Risk Assessment for Life Cycle Management and Failure Reporting Systems
Task 3 Report: Failure Reporting Systems

Submitted to
The Bureau of Safety and Environmental Enforcement
(BSEE)

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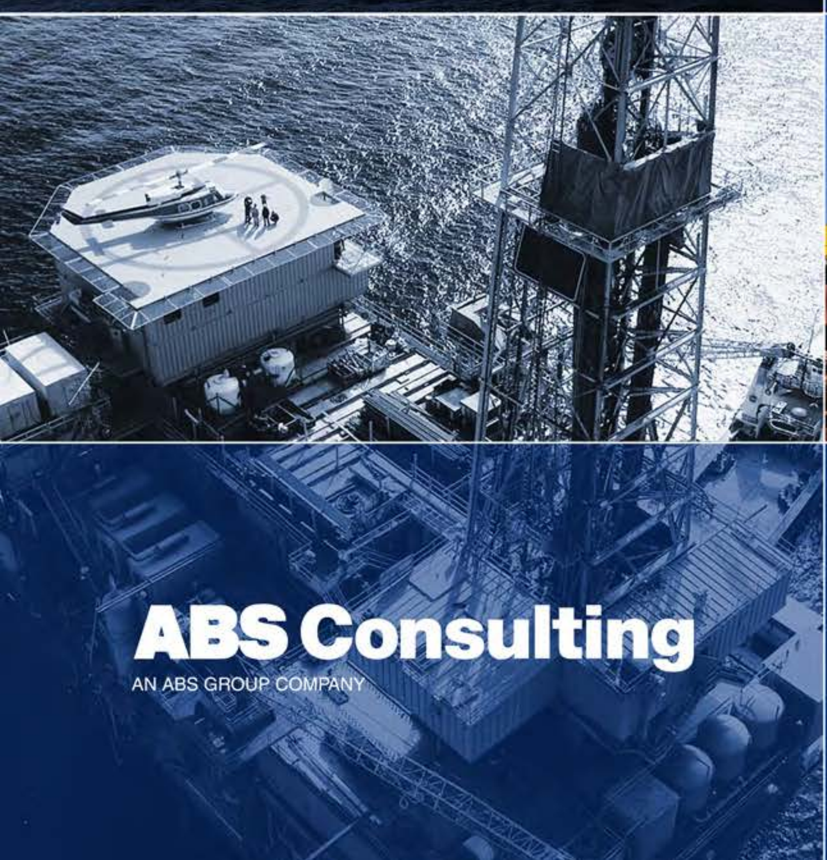

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Executive Summary

The American Bureau of Shipping (ABS) Consulting prepared this report on failure reporting systems for the Bureau of Safety and Environmental Enforcement (BSEE) to provide support in development of a risk management system. The goal of the report is to enhance efficiency, effectiveness, and risk reductions in the regulated Oil and Gas (O&G) industry.

Based on the findings from the Task 1 Report, ABS Consulting conducted a further analysis of selected agencies and industry organizations. Each agency and organization was reviewed for further programmatic elements, best practices, the role of the regulated industry, effectiveness, data, and the onus of liability.

ABS Consulting's review indicates that failure reporting is in wide use by regulatory bodies and industry; however, the purpose of the systems, types of failure reporting, their degree of prescriptiveness, types of incidents covered, and the historical institutionalization of these systems vary greatly. In this Task 3 Report, we conducted a review of the following agencies and organizations:

- Domestic Agencies
  - Department of Homeland Security: United States Coast Guard
  - Department of Defense (DoD)
  - Department of Transportation (DOT): Federal Highway Administration (FHWA)
  - Department of Transportation: Pipeline and Hazardous Materials Safety Administration
  - Nuclear Regulatory Commission

- International Agencies
  - New Zealand Department of Labor
  - Norway Petroleum Safety Authority
  - United Kingdom (UK) Health and Safety Executive

- Industry Organizations
  - American Petroleum Institute
  - International Association of Drilling Contractors
  - International Organization for Standards
  - Industry Representative Companies

- Software Providers
  - International Business Machines
  - PTC
  - ALD Services
  - Reliasoft

One of the first distinctions found is the tendency of an agency to use broad, non-exclusive levels of requirements for failure reporting, rather than a simple failure reporting system with an involved failure reporting corrective action system. Several of the industry standards provide a simple reporting mechanism, while the more prescriptive programs like DoD's Failure Reporting, Analysis, and Corrective Action System implement a feedback loop to include the Original Equipment Manufacturers (OEMs) as a means of implementing continuous improvement.

Due to the potentially sensitive nature of the data being provided and collected, data issues are paramount. Data aggregation is key for understanding and identifying trends across an industry. Many of the international and industry standards do not require data reporting directly, resulting in company-specific data. The DOT's FHWA provides a form and template for the requested data, but to achieve compliance and uniformity across the data, FHWA's process impacts the budgetary and appropriations processes for the states and for Congress.

The same liability issues presented in the Task 2 Report on Life Cycle Management (LCM) Systems would also apply to failure reporting, but with more impact or consequence. Since LCM systems are largely maintenance focused, failure of the LCM system may not result in a reportable incident. A failure of a failure reporting system could result in reportable incidents not being reported or increased potential for negative outcomes from the publishing of company-specific and company proprietary information.

Successful programs are clear and uniformly understood by the industry. Having a reporting mechanism to the OEM is a useful function, but having clear accountability of compliance with reporting is vital to ensure usable data. If the focus of compliance is on reporting, then industry may be more likely to participate. A focus on reporting compliance should not reduce the emphasis on the quality of the data reported. However, establishing a clear and understood standard of what is reportable and having a simple mechanism for reporting, aligned with industry practice, should help ensure compliance with failure reporting requirements.

The distinction between simple failure reporting systems and those with the corrective action feedback component impacts the outcome of the failure reporting process. Simple failure reporting as implemented in the UK and Norway collects, compiles, and publishes data for others to use or analyze, but does not provide guidance, corrective action, or improvements. Having a corrective action system addresses past failures and provides an opportunity to reduce the likelihood of a similar event occurring again in the future. However, this approach still only focuses on failures actually experienced and does not typically address any potential, new or emerging issues.

Failure reporting systems are a key part of a broader asset management approach and should be paired with other systems like a LCM system or a Safety and Environmental Management System. As found in many companies in the O&G industry, failure reporting is often already integrated into other management systems and processes. Given that failure reporting is by its nature a reactive system, even if corrective action is integrated, this pairing with preventative approaches would provide a process to identify issues and address concerns, both before and after an incident occurs.

If BSEE implements a failure reporting requirement, BSEE should provide clear and uniform standards of incidents to be reported, reporting requirements, and a set data structure. This will aid industry in identifying the specific equipment or components of concern and help ensure applicability across the industry. This data should be used to address past failures, provide feedback to the equipment manufacturers, and allow regulators to have the data analysis capabilities to prioritize concerns, monitor compliance, and assess trends. Many agencies also use risk-based decision-making tools to analyze the failure data to separate pressing issues from non-critical incidents.

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AASHTO	American Association of State Highway and Transportation Officials
ABS	American Bureau of Shipping
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
API	American Petroleum Institute
ATR	Automatic Traffic Recorders
BIFA	Buses in Fatal Accidents
BOP	Blowout Preventer
BSEE	Bureau of Safety and Environmental Enforcement
CAPV	Composite Air Pressure Vessel
CASREP	Casualty Report
CCFDB	Common Cause Failure Database
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CG-ENG	USCG Office of Design and Engineering Standards
CGMIX	Coast Guard Maritime Information Exchange
CGTO	Coast Guard Technical Order
CO_2	Carbon dioxide
CODAM	Corrosion and Damage
DDRS/CDRS	Daily/Common Drilling Reporting System
DIMP	Distribution Integrity Management Program
DoD	Department of Defense
DOT	Department of Transportation
DHS	Department of Homeland Security
DSYS	Driving-Related Accidents (Norwegian)
EEZ	Exclusive Economico Zone
EPA	Environnemental Protection Agency
EPIM	Exploration and Production Information Management Association
EPIX	Equipment Performance and Information Exchange
EPLC	Enterprise Performance Life Cycle
EU	Européen Union
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FRB	Failure Review Board
H_2S	Hydrogen sulfide
HCA	High Consequence Areas
HPMS	Highway Performance Monitoring System
HSE	Health and Safety Executive (Britain)
IADC	International Association of Drilling Contractors

IAEA	International Atomic Energy Agency
IBM	International Business Machines
IM	Integrity Management
IMHH	Industry Mutual Hold Harmless
IRS	International Reporting System
ISO	International Organization for Standardization
ISP	Incidents Statistics Program
KP4	Ageing and Life Extension Key Program
L2S	License2Share
LCA	Life Cycle Assessment
LCM	Life Cycle Management
LER	Licensee Event Report
LERSearch	Licensee Event Report Search
MAP-21	Moving Ahead for Progress in the 21st Century Act
MARS	Major Accident Reporting System
MDOT (MD)	Maryland Department of Transportation
MDOT (MI)	Michigan Department of Transportation
MHIDAS	Major Hazard Incident Data Service
MISLE	Marine Information for Safety and Law Enforcement
MODU	Mobile Offshore Drilling Units
NCS	Norwegian Continental Shelf
NHS	National Highway System
NJDOT	New Jersey Department of Transportation
NMSRA	National Maritime Strategic Risk Assessment
NPRDS	Nuclear Plan Reliability Data System
NRC	Nuclear Regulatory Commission
OCS	Outer Continental Shelf
OEM	Original Equipment Manufacturer
O&G	Oil and Gas
OREDA	Offshore Equipment Reliability Database
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline Hazardous Materials Administration
PIM	Pipeline Integrity Management
PPB	Parts Per Billion
PPM	Parts Per Million
PSA	Petroleum Safety Authority (Norway)
RIDDOR	Reporting of Injuries, Diseases, and Dangerous Occurrences
RM	Reliability Maintenance
RP	Recommended Practice
ROV	Remotely Operated Underwater Vehicle
RQ	Reportable Quantity
RUG	Regional User Group

SAICM	Strategic Approach to International Chemicals Management
SCSS	Sequence Coding and Search System
SEMATEC	Semiconductor Manufacturing Technology Consortium
SEMS	Safety and Environmental Management System
SITP	Shut-In Tubing Pressure
SME	Subject Matter Expert
SMS	Safety Management System
SSV	Surface Safety Valve
SSSV	Subsurface Safety Valve
SWS	Service Water System
TIFA	Trucks in Fatal Accidents
UK	United Kingdom
U.S.	United States
USCG	United States Coast Guard
USV	Underwater Safety Valve
VDOT	Virginia Department of Transportation
WBIRS	Web-Based Incident Reporting System

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1. Introduction

This report compiles results from inquiries and analyses in support of contract E14PB00045, to identify and evaluate failure reporting concepts for equipment used in Outer Continental Shelf (OCS) Oil and Gas (O&G) operations and recommend changes to 30 CFR 250. In keeping with the Bureau of Safety and Environmental Enforcement's (BSEE) mission, this Task 3 report provides a review of failure reporting systems and recommends improvements that BSEE can implement. The project focuses on answering the who, what, when, and why concerning the equipment and components that should be included in a failure reporting system.

To support continued improvement of BSSE oversight of risk mitigation, BSEE should have readily accessible information about how other agencies and firms are successfully managing risk using failure reporting systems. BSEE can learn from authenticated and evolving best practices for failure reporting systems for risk management of critical components. American Bureau of Shipping (ABS) Consulting views industry participation as integral to a successful regulatory program. For each organization and agency we reviewed how industry standards, input, and practices are addressed and incorporated. Following the review of the selected agencies and organizations, recommendations are provided to BSEE for consideration in determining the best approach to regulatory actions.

BSEE currently incorporates American Petroleum Institute (API) Specification Q1, Eighth Edition (Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry) into its regulations (Code of Federal Regulations (CFR), 2015). This specification addresses risk management in manufacturer quality programs. Additionally, industry has developed API Specification Q2 (Specification for Quality Management System Requirements for Service Supply Organizations for the Petroleum and Natural Gas Industries), which addresses risk management in service sector products and services. API Specification 18LCM is in the early stages of development. It will specifically address Life Cycle Management (LCM) from concept through decommission, as well as failure reporting, likely leveraging API Specifications Q1 and Q2. As BSEE reviews failure reporting systems for their applicability to BSEE jurisdiction, API Specification Q2 and Q3 will also be considered for BSEE to incorporate into its regulatory program.

2. Objectives and Purpose

In the wake of the Deepwater Horizon disaster, the regulatory community has placed increasing emphasis on understanding effective rulemaking regarding failure prevention and reporting. Failure reporting provides a way for the O&G industry to monitor how well a piece of equipment, or any component on a piece of equipment, performs its job. If failure occurs, failure reporting provides a signal to other users of similar equipment/components of an exposed problem and gives investigators the best chance to determine the root cause of an incident and make corrections.

The objective of this report is to provide some answers to selected research questions provided by BSEE. Expanding on the results of Task 1, this task further analyzes previously identified failure reporting systems. In order to support BSEE in development and administration of an effective and efficient regulatory program based on risk management for OCS O&G operations, this project will generate a base of knowledge from existing regulations and private sector programs that define best failure reporting practices in relevant arenas.

This report further identifies the key elements of a failure reporting system, the policies and regulations enacted, activities of responsible parties, and the different approaches used to implement or regulate a failure reporting system. Following the review of the selected agencies, several findings that are applicable to BSEE are provided to aid BSEE in strengthening their regulatory-related guidance document processes to enable greater effectiveness and flexibility in regulating a complex and fast-paced industry.

This report aims to validate and expand the findings from Task 1 of what constitutes a successful failure reporting system. Evaluation of the findings focused on the following areas: how these systems were built; how they currently operate; system effectiveness; system adoption by the regulated industry; and failure reporting systems concepts and methodologies for formulation of a failure reporting system suited to BSEE.

3. Approach

Our assumptions and theories developed in Task 1 were verified and further developed in Task 3. Aspects such as feedback mechanisms and inputs were analyzed for each failure reporting system to evaluate the effectiveness of the system. ABS Consulting approached Tasks 2 and 3 simultaneously. We analyzed agencies and organizations identified in Task 1 to verify, validate, or discern the validity and functionality of LCM in Task 2 and their failure reporting systems in Task 3.

Research Approach

ABS Consulting conducted outreach to the selected agencies and coordinated with our international offices to obtain information for international regulators. We used a standard template to review and collect uniform data for each identified program to learn consistent information as a baseline.

In order to address the research question in this report, ABS Consulting researched publicly available documentation for each of the indicated agencies and failure reporting systems. We also evaluated available failure reporting data and reviewed the appropriate scientific literature on failure reporting effectiveness. In addition, ABS Consulting conducted formal and informal interviews with in-house Subject Matter Experts (SMEs) and, where appropriate, engaged in informal outreaches to industry SMEs. In order to balance parsimony with utility, ABS Consulting performed an in-depth review of the United States Coast Guard (USCG). This approach was chosen to take advantage of both the shared regulatory space and dual mandate that BSEE and the USCG serve.

Analysis Approach

The scope of failure reporting systems in the offshore O&G industry is extensive. In order to efficiently display the information for the agencies and systems identified, we opted to organize the analysis in two ways. First, ABS Consulting answered each research question posed by BSEE by gathering relevant information for each agency. Once all the information for each agency was collected, we reviewed data across the systems to identify key commonalities and components, trends, viability, and applicability to BSEE. Given the list of selected agencies, some programs did not hold up to further scrutiny. Ensuring the functionality, viability, and acceptance by the industry will be key in understanding how to best implement a failure reporting system.

ABS Consulting analyzed our findings to provide feedback and options for progress forward. As a result of our Task 3 efforts, ABS Consulting is providing preliminary recommendations for failure reporting systems, that along with our Task 2 – LCM Findings, will inform Tasks 4 and 5.

4. Agency Review

The following section is an in-depth review of organizations initially identified in the Task 1 report and subsequently requested by BSEE for further review. This section is separated into three sections: Domestic Federal Agencies, International Regulators and Industry. Each organization reviewed in this section has been researched to identify the elements listed in the BSEE Task 3 Statement of Work for this project.

4.1 Domestic Federal Agencies

The information in this sub-section describes the data collected for the following organizations: the Department of Defense (DoD), two organizations within the Department of Transportation (DOT), the Federal Highway Administration (FHWA) and Pipeline and Hazardous Materials Safety Administration (PHMSA), the Nuclear Regulatory Commission (NRC) and the USCG.

4.1.1 Department of Homeland Security – United States Coast Guard

Failure reporting is a key component of the Department of Homeland Security's (DHS) USCG efforts to promote safety and environmental protection and is part of USCG's LCM system (covered in Task 2 Report LCM Systems). Since the USCG both regulates maritime transportation and manages their own operational assets, they developed and manage two separate failure reporting systems, one for failures of internal USCG equipment and one for failures of critical equipment and systems in the regulated industry.

In August, 1983, USCG's current marine casualty investigation program for the commercial maritime industry was codified in 46 USC 6301. That same year, 46 USC 3717 required USCG to establish and maintain a system to collect the "histories of vessels that operate on the navigable waters of the United States (U.S.)" (U.S. Coast Guard, 2006).This system came to include a history of marine casualties that encompassed equipment failures. Currently, that system of collection is managed through USCG's Marine Information for Safety and Law Enforcement (MISLE) database. Subsequently, in May of 1986, the USCG issued implementation regulations in 46 CFR Part 4, which defines a marine casualty and the reporting requirements.

In addition to their external policies, USCG has well-established policies and procedures for reporting equipment failures for their internal systems. While marine casualty guidelines are established for external events, USCG refers to its internal failure reporting as Casualty Reports (CASREP). Based on ABS Consulting SME insight, these policies and procedures were initially developed by the U.S. Navy over 30 years ago, and then later adopted by USCG. The purpose of the CASREP system is to inform the USCG chain of command when there are operational limitations due to equipment failures. The CASREP system also informs logistics managers of the need for technical assistance, parts, and repairs required to restore an asset to full capability. The USCG is now on the seventh iteration of these policies and procedures and has gained a wealth of experience in using a failure reporting system to inform its operations and LCM policies and procedures. To reiterate, direct application of USCG's failure reporting to the OCS may be difficult, but CASREP structures and processes could assist BSEE in framing a program.

4.1.1.1 *Information, Policies, and Procedures*

The primary purpose of the USCG's marine casualty investigation program for the maritime industry is to assist the USCG in responding to marine casualties and conducting timely investigations that lead to findings that promote safety and protect the environment. The USCG defines "marine casualty or accident" as:

§4.03-1 Marine casualty or accident.

Marine casualty or accident means—

(a) Any casualty or accident involving any vessel other than a public vessel that—

(1) Occurs upon the navigable waters of the United States, its territories or possessions;

(2) Involves any United States vessel wherever such casualty or accident occurs; or

(3) With respect to a foreign tank vessel operating in waters subject to the jurisdiction of the United States, including the Exclusive Economic Zone (EEZ), involves significant harm to the environment or material damage affecting the seaworthiness or efficiency of the vessel.

(b) The term 'marine casualty or accident' applies to events caused by or involving a vessel and includes, but is not limited to, the following:

(1) Any fall overboard, injury, or loss of life of any person.

(2) Any occurrence involving a vessel that results in—

(i) Grounding;

(ii) Stranding;

(iii) Foundering;

(iv) Flooding;

(v) Collision;

(vi) Allision;

(vii) Explosion;

(viii) Fire;

(ix) Reduction or loss of a vessel's electrical power, propulsion, or steering capabilities;

(x) Failures or occurrences, regardless of cause, which impair any aspect of a vessel's operation, components, or cargo;

(xi) Any other circumstance that might affect or impair a vessel's seaworthiness, efficiency, or fitness for service or route; or

(xii) Any incident involving significant harm to the environment.

(3) Any occurrences of injury or loss of life to any person while diving from a vessel and using underwater breathing apparatus.

(4) Any incident described in §4.05-1(a) (Commandant Instruction M16000.10A, USCG Marine Safety Manual, VOLUME V Investigation and Enforcement, 2008).

The regulations in 46 Code of Federal Regulations (CFR) Part 4 do function as a failure reporting system, but the scope and purpose of the regulations are much broader than tracking equipment failures. Though reports of equipment failures are required by 46 CFR 4.5-01(a) (3), (4), they are limited to:

(3) A loss of main propulsion, primary steering, or any associated component or control system that reduces the maneuverability of the vessel; [or]

(4) An occurrence materially and adversely affecting the vessel's seaworthiness or fitness for service or route, including but not limited to fire, flooding, or failure of or damage to fixed fire-extinguishing systems, lifesaving equipment, auxiliary power-generating equipment, or bilge pumping systems (Department of Homeland Security, 2015).

Therefore, an equipment failure alone does not constitute a reportable marine casualty unless the failure contributed to one of the occurrences delineated in these two sections of the regulation. As such, the USCG's failure reporting system for industry is predicated on the consequences of equipment failures, not simply the equipment failures themselves. This implies that many equipment failures may not be reported to or investigated by the USCG. However, emphasis in the definition on human safety, in addition to environmental harm, underscores the fact that this failure reporting system collects data based on outcomes, not on events. While this closely aligns with the USCG's established goals, a distinct weakness in this system is that it cannot readily be used to predict accidents or hazards, should certain events related to the negative outcomes occur. Accounting for those equipment failures closely associated with casualties or accidents could enhance the USCG's ability to proactively prevent their occurrences.

As previously discussed, the USCG uses the CASREP system to report and track failures associated with USCG operational assets. The four primary policy documents that inform the CASREP process are:

- Commandant Instruction 3501, CASREP Procedures (Materiel) Manual
- Coast Guard Technical Order (CGTO) PG-85-00-640-S, Surface Forces Logistics Center Non-Integrated Asset CASREP Process Guide
- Operational Reports, Naval Warfare Publication 1-03.01
- Coast Guard Tactics, Techniques, and Procedures 6-01.3A

These policies state that a CASREP must be submitted for an equipment malfunction or deficiency that cannot be corrected within 48 hours, and also:

- Reduces a unit's ability to perform a primary mission
- Reduces a unit's ability to perform a secondary mission
- Reduces training command's ability to perform its mission and would require the rescheduling of lessons or classes

It must be noted that, like the maritime casualty system, the CASREP system, as implemented, does not capture all equipment failures of USCG assets. Once again broad in nature, the conditions that trigger a report for an equipment malfunction depend on the failed element's effect on the entire unit. The development of a comprehensive failure reporting system, as discussed in the Recommendations section of this report, or near-miss recognition process could better enable operators and USCG to monitor performance and track failures without an initial accident or casualty from occurring.

It is also important to note that the CASREP system applies exclusively to USCG vessels and shore-side facilities. The CASREP process does not apply to aviation or major electronic assets, which have separate failure reporting processes. Within the CASREP system, there are three casualty categories that reflect the urgency or priority of the CASREP.

- Casualty Category 2
  - The inability to perform any primary mission because of a deficiency in mission essential equipment
  - A vessel is unable to complete certain mission essential tasks, but the vessel remains nearly fully mission capable
  - A minor mission degradation such as equipment, machinery, and systems operating at reduced capacity or redundancy

- Casualty Category 3
  - Major impacts that include complete loss of equipment, systems, or machinery functions that significantly reduce mission effectiveness through incapacity to complete several mission essential tasks, but the vessel remains partially mission capable

- Casualty Category 4
  - Total loss of one current mission, vessel unable to operate as directed or without significant risk to cutter/crew survivability

The USCG adopted the CASREP categories from the U.S. Navy, which also has a Casualty Category 1 policy. In addition to the above categories, there are also four specific types of CASREPs: Initial, Update, Correct, and Cancel. Initial CASREPs are used to identify the status of the casualty and the parts or assistance required. They also notify the operational and support organizations of the loss of an asset's capability. Update CASREPs are used to provide new or more complete information supporting the Initial CASREP. Update CASREPs are sent every 30 days or within 24 hours of a status change. Correct CASREPs are used to provide information when equipment is repaired and in operational condition.

Finally, Cancel CASREPs are used to terminate the Initial CASREP and all subsequent Update CASREPs, and close out the reporting process.

The USCG does not use, or require the use of, any for-profit failure reporting systems that are available on the open market; therefore, an evaluation of cost to participate and their historical performance is not possible.

4.1.1.2 *Elements, Best Practices, Lessons Learned*

The USCG analyzes marine casualty reports to determine if there are potential manufacturing defects. The USCG has the authority to compel changes from the manufacturers of materials or equipment regulated by 46 CFR Subchapter Q. The USCG can revoke the manufacturer's approval to produce USCG approved equipment if defects are not corrected (Commandant Instruction 16000.7B, Marine Safety Manual Volume II, Materiel Inspection 2014). However, no specific data on the USCG revoking a particular Original Equipment Manufacturer's (OEM) approval could be found. The USCG also issues "Safety Alerts" to notify the industry stakeholders of potential issues and lessons learned from the failure reports.

As mentioned in the previous section, USCG's failure reporting system is based on the consequences that arise when a piece of equipment fails, rather than the actual equipment failure. Therefore, while a piece of equipment may fail, the USCG's primary concerns are to human and environmental safety. In accordance with safety of human life, listed below are incidents which are Reportable Marine Casualties under 46 CFR 4.05-1:

- An unintended grounding or unintended collision with a bridge;
- An intended grounding or intended collision with a bridge that creates a hazard to navigation, the environment or the safety of a vessel;
- A loss of main propulsion, primary steering or any associated control system that reduces the maneuverability of the vessel;
- An occurrence materially and adversely affecting the vessel's seaworthiness or fitness for service or route;
- A loss of life;
- An injury that requires professional medical treatment beyond first aid, and if the person is employed on a commercial vessel, that renders the person unfit for duty; or
- An occurrence causing property damage in excess of $25,000 (United States Coast Guard, 2014).

Additionally, 46 CFR 4.03-2 dictates a Serious Marine Incident is a Reportable Marine Casualty that results in one or more of the following events:

- One or more deaths;
- An injury to a crewmember, passenger, or other person which requires professional medical treatment beyond first aid and, if the injured party is a crewmember, renders the individual unfit to perform routine vessel duties;
- Damage to property in excess of $100,000;

- Actual or constructive total loss of any vessel subject to inspection under 46 USC 3301;
- Actual or constructive total loss of any self-propelled vessel, not subject to inspection under 46 USC 3301, of 100 gross tons or more;
- A discharge of oil of 10,000 gallons or more into the navigable waters of the U.S., whether or not resulting from a marine casualty; or
- A discharge of a Reportable Quantity (RQ) of a hazardous substance into the navigable waters of the U.S., or a release of a RQ of a hazardous substance into the environment of the U.S., whether or not resulting from a marine casualty (United States Coast Guard, 2014).

In reference to the environmental safety aspects as they relate to USCG's failure reporting system, 46 CFR 4.5-1(a)(8) requires the reporting of "An occurrence involving significant harm to the environment as defined in 4.03-65." The regulation in 46 CFR 4.03-65 defines significant harm to the environment:

(a) In the navigable waters of the United States, a discharge of oil as set forth in 40 CFR 110.3 or a discharge of hazardous substances in quantities equal to or exceeding, in any 24-hour period, the reportable quantity determined in 40 CFR part 117;

(b) In other waters subject to the jurisdiction of the United States, including the EEZ—
   1) A discharge of oil in excess of the quantities or instantaneous rate permitted in 33 CFR 151.10 or 151.13 during operation of the ship; or
   2) A discharge of noxious liquid substances in bulk in violation of §§153.1126 or 153.1128 of this chapter during the operation of the ship; and

(c) In waters subject to the jurisdiction of the United States, including the EEZ, a probable discharge of oil, hazardous substances, marine pollutants, or noxious liquid substances. The factors you must consider to determine whether a discharge is probable include, but are not limited to—
   1) Ship location and proximity to land or other navigational hazards;
   2) Weather;
   3) Tide current;
   4) Sea state;
   5) Traffic density;
   6) The nature of damage to the vessel; and
   7) Failure or breakdown aboard the vessel, its machinery, or equipment.

These three components of 46 CFR provide the guidelines and organization for when a particular incident occurs. As mentioned before, USCG looks at failure reporting based on the incidents that result, rather than the failure of a piece of equipment. These definitions are ultimately used when industry members report the occurrence of a particular event. While the methods and guidelines of reporting from industry members is explored in the subsequent section, it is important to understand the definitions and guidelines presented above inform the basis for the type and content of the reportable event.

For USCG's internal CASREP system, extensive labeling, formatting, and data requirements are implemented. First, the report must be classified as unclassified, confidential, or secret. Second, a casualty category provided that reflects the urgency or priority of the CASREP and details on the various Casualty Categories are provided in the previous section. Third, writers of the reports must supply appropriate addresses of the incident and where the equipment is located. Finally, the precedence must be defined as one of the following: routine, priority, immediate, or flash.

Once a CASREP is complete, all of the text within a CASREP is contained in formatted lines called data sets. Each data set contains specific information in a certain order, starting with a set identifier and followed by a group of information called data fields. The format and placement of this information within the CASREP is important because improperly formatted CASREP data cannot be processed by the automated processing system (United States Coast Guard, 2013). Additionally, a properly formatted CASREP will provide useful datasets that can in turn be used to identify different types of data such as basic information of a particular incident and information used to explain the symptoms of the reported marine casualty.

A final point to note for the USCG's failure reporting system is that while this approach may not serve to avoid equipment failures and human and environmental incidents in the future, USCG has begun to take steps towards programs that will forecast an issue before it occurs. One such step is a risk-based approach towards planning and allocation of resources. While the purpose of this report is not to analyze USCG's risk-based approaches, two programs are of note:

- National Maritime Strategic Risk Assessment (NMSRA) – This program serves to provide risk assessments for all hazards for all missions. This program is designed to provide decision makers with a complete overview of all risks within the marine environment over the next five to eight years (U.S. Coast Guard, 2013).
- Risk Management Module – This program is based off of NMSRA and builds a field level mission risk analysis (U.S. Coast Guard, 2013).

These two programs, while not specific to failure reporting, theoretically would provide insight into the potential failures, consequences and risks of maritime equipment.

4.1.1.3 *Role of Industry*

There are failure reporting systems utilized by individual companies and industry trade groups or associations that inform USCG process, but USCG does not access or use the data from those reporting systems. Therefore, USCG maintains reporting requirements for owners and operators within the industry.

In 46 CFR Part 4, there are two primary regulatory requirements for reporting marine casualties. The first is Initial Notification and the second is Written Notification. The Initial Notification, as per 46 CFR, Part 4.05-1, requires that immediately upon addressing all resultant safety concerns, the owner, operator, agent, master or person in charge of a commercial vessel shall notify the USCG when a marine casualty has occurred (Department of Homeland Security, 2015). This immediate notification shall be made via telephone or e-mail. The Written Report, as per 46 CFR, Part 4.05-10, requires that in addition to the initial notification, a written report of a marine casualty shall be submitted to the USCG using form CG-2692 within 5 days of the incident (Department of Homeland Security, 2015). The CG-2692 shall be filled out as completely and accurately as possible. It should be noted that "marine casualty" used in these two reporting requirements are based off the previously mentioned definitions.

Once an industry member reports the occurrence of an event to USCG, USCG then begins to take several steps in an attempt to identify the underlying causes of why that incident occurred. This investigation could result in the determination of underlying defects within a particular piece of equipment. In those instances, as noted in Figure 1 below, an equipment manufacturer may be notified to correct the defect and recall the defective products. Figure 1 below provides a general overview of the steps the USCG takes once an incident is reported to them.

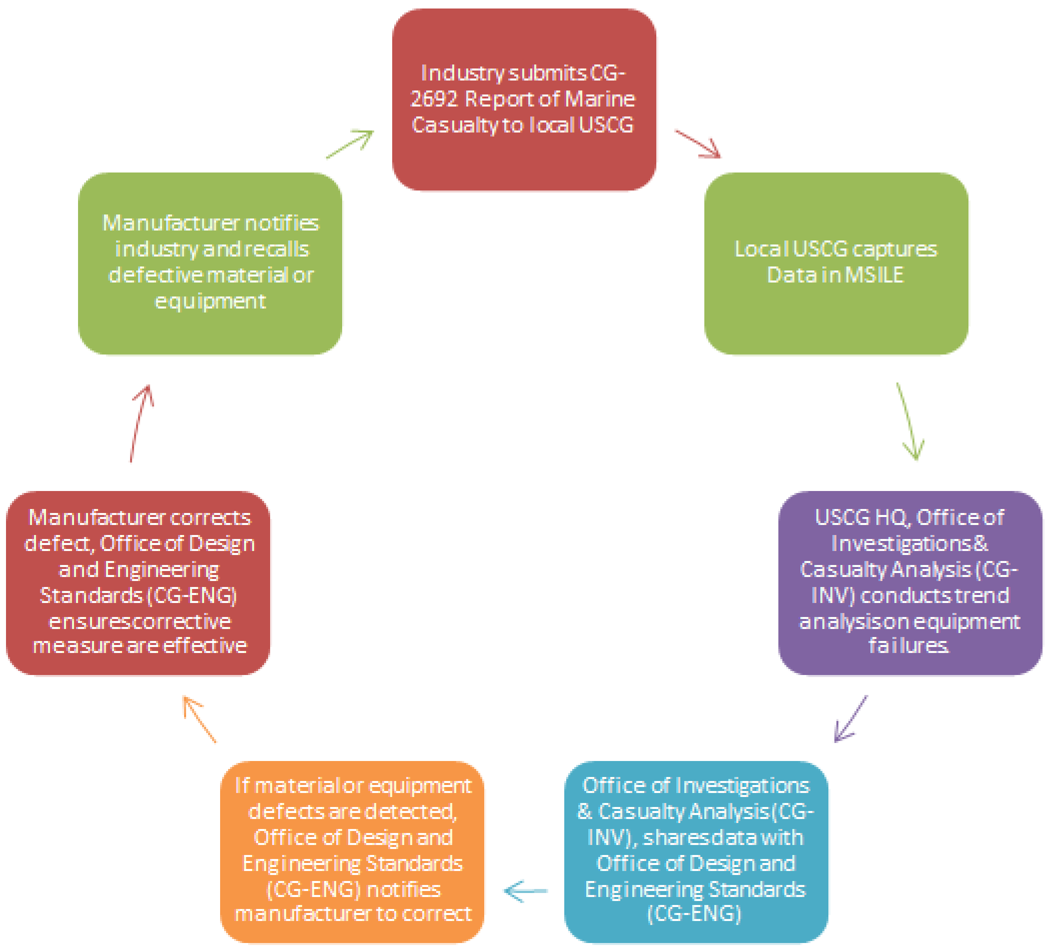


Figure 1: USCG Incident Reporting Process Flowchart

There are two important points to note within the USCG incident reporting process above; first, not all incidences reported to USCG will necessarily result in a product recall; and second, after reporting an incident, USCG captures this data in their MISLE database. Reporting of an incident and the subsequent investigation may result in an actionable outcome to a regulatory body instead of to an industry member.

The capture of the data in MISLE is critical in identifying trends of incidences over an extended timescale and across geographical areas. The overall effectiveness and utility of the collection of data within MISLE is provided in Section 4.1.1.4, but it is important to recognize the significance of capturing data, as an incident occurring may result in no other outcome other than simply providing another data point.

4.1.1.4 *Effectiveness*

USCG's MISLE database is the central repository for all inspection data and is the primary information source for inspection and investigation work. MISLE is one of the data sources that support key USCG management decisions, such as establishing human capital requirements, quantifying resource shortfalls, and reallocating existing resources. The MISLE database is also USCG's primary system for documenting marine casualties required to be reported by 46 CFR. MISLE has one of the most, if not the most, comprehensive collections of data regarding marine casualties. Only USCG-authorized employees can access the database.

USCG posts the data collected from marine casualties in MISLE to the Coast Guard Maritime Information Exchange (CGMIX) website. The CGMIX website makes incident investigation reports available to the public in a searchable online database. The CGMIX database is a useful tool, but its online configuration makes it difficult to conduct an analysis of equipment failures. For example, a keyword search of the term "equipment failure" in the database can yield thousands of results, but because there are no defined subcategories of the term, it is difficult to categorize equipment failures. Searches can be narrowed by using more specific keywords. For example, a search for the keyword "generator" yields over 250 records. Though this is a more manageable number, each record has to be opened, analyzed, and categorized in a separate database to be useful. As a database, it is effective in gathering and maintaining the data, but not very useful in the event the data needs to be recalled.

With MISLE, USCG theoretically possesses the data necessary to address the effectiveness of their failure reporting systems. This should allow USCG to employ a variety of effectiveness measurement targets to communicate the success of its prevention programs. The following are a few examples of these effectiveness measures:

- "The five-year average number of commercial mariner deaths and injuries;
- "The five-year average number of commercial passenger deaths and injuries;
- "The five-year average number of maritime injuries;
- "The five-year average number of oil spills into the marine environment per 100 million short tons shipped;

- “The five-year average number of chemical discharges into the marine environment per 100 million short tons shipped” (Independent Evaluation USCG Prevention Program, 2009).

Because USCG processes thousands of reports of marine casualties every year and maintains a comprehensive source of data regarding these reports, they have recently explored the overall effectiveness of their reports and data management. Unfortunately, USCG’s marine casualty program recently came under criticism from the Office of the Inspector General for the DHS. In 2013, an Inspector General’s audit found that:

> …the USCG has not developed and retained sufficient staff, ensured all corrective actions are addressed and implemented, and needs to enforce requirements related to reporting marine accidents consistently. As a result, it may be delayed in identifying causes of accidents; initiating corrective actions, and providing the findings and lessons learned to mariners, the public, and other government entities. These conditions may also delay the development of new standards, which could prevent future accidents. (Marine Accident Reporting, Investigations, and Enforcement in the United States Coast Guard, 2013)

This report highlights that while the overarching regulations and guidelines may be in place, USCG is lacking in its ability to mitigate future accidents from occurring. USCG’s failure reporting system may be effective in establishing guidelines, but is not effective in producing actionable analysis.

4.1.1.5 *Outcomes*

The logic model in Figure 2 represents a high-level hypothetical representation of the USCG prevention program and relates program mission activities to organizational outcomes (the number of fatalities, injuries, and damage to the environment over time). The figure shows the inputs applied to the prevention program mission activities. The mix of resources and mission activities leads to mandated mission outputs. Finally, the mission outputs are evaluated for organization outcomes, which describe the prevention program effectiveness (Independent Evaluation USCG Prevention Program, 2009).

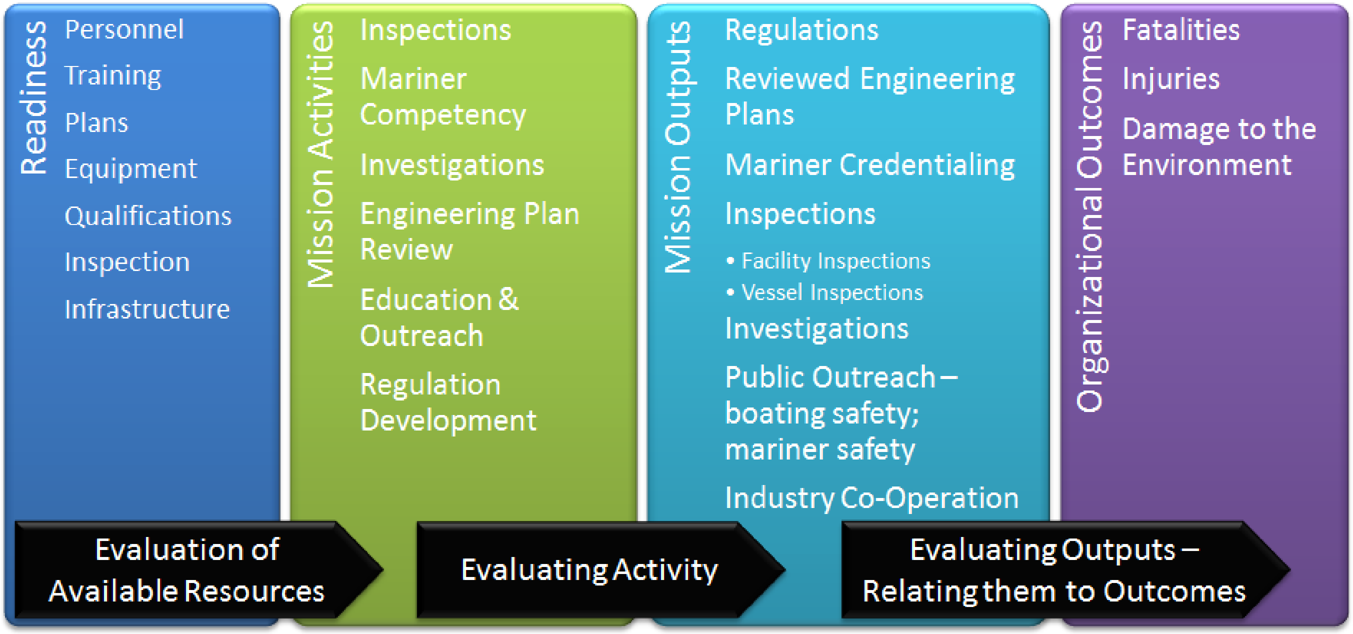


Figure 2: USCG Prevention Program Flowchart
(Independent Evaluation USCG Prevention Program, 2009)

4.1.1.6 *Data*

Since 2002, the USCG has issued twelve "Lifesaving Equipment Safety Alerts" and initiated two recalls of defective equipment. These safety alerts and product recalls (listed below) are available at: http://www.uscg.mil/hq/cg5/cg5214/recalls.asp.

List of Lifesaving Equipment Safety Alerts

- Misthreaded Strap on NRS Zen PFD – October 2014
- Mislabeled Intended Use on Extraport Model UT3-5 – September 2014
- Unapproved EPIRB Battery Replacements – September 2009
- Fake Hammer HRU's, Updated Information – March 2009
- Fake Hammar HRUs – December 2008
- SWITLIK Liferaft Inflation Valves – June 2008
- Improperly Installed CO2 Cylinders in Inflatable PFDs – June 2005
- Non-Serviceable Foam Life Preservers – May 2005
- Loosening of Critical Fasteners – February 2005
- Lifejacket Snap Hooks – May 2004
- Lifeboat Gripes – March 2004
- Lifeboat Release Mechanisms – January 2004

Equipment Recall Notices

- November 26, 2008. ACR EPIRB recall
- August 28, 2002. SOS Inc. Inflatable Life Jackets Equipped With The Hammar Model MA1 Manual/Automatic Inflators

As mentioned in the previous section, the primary data repository for the occurrence of maritime incidents is MISLE. While MISLE can provide broad range of specific detail as it relates to an incident, it is not particularly user-friendly when attempting to recall and analyze the actual data. In addition, since a large portion of the inputted data is done by hand, there are many input errors captured through the data collection process. No specific data is available on the program's effectiveness based on the prevalence or avoidance of various consequences.

The lack of available data that can produce actionable analysis is also indicated in the comments provided by the DHS Inspector General and the audit conducted by that office. Though MISLE datasets could theoretically be used alongside the previously mentioned NMSRA program to help predict failure of equipment and systems before they occur, unfortunately, MISLE's lack of a user-friendly structure prevents the development of program effectiveness data.

4.1.1.7 *Liabilities*

The liability for USCG in regards to CASREP has some significance. The monitoring and enforcement regulations that apply to the prevention of human injury and death or environmental harm carry with them higher levels of public scrutiny. USCG's failure reporting system is prescriptive in nature, as it reflects these smaller margins for error.

4.1.1.8 *Application to BSEE*

Since the USCG's CASREP system is focused on internal equipment, it is of less applicability to BSEE than the marine casualty reporting system and its corresponding MISLE database, which do provide useful examples from which BSEE's own failure reporting system can be developed. The comprehensiveness of MISLE data in particular lends itself readily as an element for BSEE to mimic. That being said, the usefulness of the data is entirely dependent on the USCG's ability to collect, analyze, and then report back to vessel operators to prevent accidents and causalities from occurring. While reporting to MISLE appears sufficient, it lacks certain elements that could make the data analyzed reflect common failures and trends in the development of accidents and casualties. Specifically, the fact that equipment failures are only reported if they correspond to a specified outcome leaves a substantial gap in the MISLE system's predictive abilities. Should BSEE choose to develop their own failure reporting system on this model, considerations for near misses and common cause occurrences need to be accounted.

4.1.2 Department of Defense – Failure Reporting, Analysis and Corrective Action System

The Failure Reporting, Analysis, and Corrective Action System (FRACAS) was developed by the U.S. Government and first introduced for use by the U.S. Navy and all DoD agencies in 1985. FRACAS is a closed-loop system that records problems related to a product or process and their associated root causes and failure analyses to assist in identifying and implementing corrective actions. FRACAS was designed to manage multiple failure reports and track failure history and corrective actions (Department of Transportation, 2015).

Before FRACAS, DoD implemented reliability programs onto their weapons systems using formal military standards. However, over the years the concepts within the reliability-based standards began to shift into industry and DoD began to shift towards "performance-based requirements." Previous reliability-based standards were cancelled due to the need to reduce weapon system acquisition cost and incentivize the industry to develop innovative technical designs (Reliability Analysis Center (RAC), 2008). While there are no specific documents that highlight the exact cause of the creation of FRACAS, we can assume the advent of FRACAS guidelines stemmed from the need to redevelop reliability-based programs and tasks.

The overall purpose of the FRACAS guidelines is to use failure and maintenance data to prevent the recurrence of failure, reduce the number of maintenance tasks, and the complexity of maintenance tasks. This purpose is accomplished by increasing the transparency of the occurrence of an event and by developing an actionable analysis based on the reporting of the event (Department of Defense, 2015). Additionally, the FRACAS program guidelines established by DoD are routinely reviewed for applicability and to ensure the guidelines are still current.

4.1.2.1 *Information, Policies, and Procedures*

The basic importance of FRACAS is centered on the idea of early elimination of the causes of a root failure. The causes of a root failure are considered a primary contributor to the reliability of a product and early elimination of those causes will reduce overall maintenance costs; costs that will only increase as implementation and verification costs of corrective action rises as the life-cycle of the product increases (Reliability Analysis Center (RAC), 2008). The fundamental characteristics of a FRACAS are:

- Recording and capturing all failures and problems related to components, processes, etc., in the development and delivery of a product or service;
- Identifying, selecting, and prioritizing failures and problems for follow-on analysis to determine their root-cause;
- Identifying, implementing, and verifying corrective actions to preclude recurrence of the root-cause failure or problem; and
- Providing all appropriate personnel with access to the failure, analysis and corrective action information to support reliability growth and proactive decisions to prevent similar problems from occurring in future products or services (i.e., "closing the loop") (Reliability Analysis Center (RAC), 2008).

DoD FRACAS is used by all branches of the DoD and includes a software system as well. Additionally, elements within FRACAS are based off of existing International Organization for Standardization (ISO) requirements, as Table 1 below highlights.

Table 1: Existing ISO Requirements

ISO 9000 Requirement	Purpose	FRACAS
ISO 9001 Section 4.1.2.1	Management Responsibility: Identify and record any product quality problems; verify the implementation of solutions	Identifies test events, failure modes, corrective actions
ISO 9001 Section 4.4.5	Design Verification: Establish that design outputs meet requirements; perform preproduction testing to verify design	Identifies test events
ISO 9001 Section 4.14	Corrective Action: Investigate cause of nonconforming product and the corrective action needed to prevent recurrence	Identifies failure modes, corrective actions

(Reliability Analysis Center (RAC), 2008)

4.1.2.2 *Elements, Best Practices, Lessons Learned*

FRACAS planning involves the preparation of written procedures for the initiation of failure reports, analysis of failures, and the feedback of corrective actions into design, manufacturing, and test process. The contractor's procedures for implementing FRACAS and for tracking and monitoring failure analysis and corrective action status need to be in the developed FRACAS plan. Flow diagrams that depict failed hardware and failure data flow are also required when developing a FRACAS plan (Reliability Analysis Center (RAC), 2008).

Moreover, a Failure Review Board (FRB) needs to be established to review failure trends, corrective actions status, and to assure adequate corrective actions are taken (Department of Defense, 2015). FRB contractor personnel would be identified in the FRACAS procedures and the scope or extent of their authority. The FRB is required to meet on a regular basis and review failure data from appropriate inspections and tests, and subcontractor test failures. The FRB has the authority to require failure investigations and analyses by other contractor organizations and to assure implementation of corrective actions. The acquiring activity reserves the right to appoint a representative to the FRB as an observer. If the contractor can identify and use an already existing function to perform the FRB functions, then a description of how the existing function will be employed to meet acquiring activity requirements needs to be provided for acquiring activity review (Department of Defense, 1985).

The results of the failure analysis should then be fed back to knowledgeable personnel so they can decide on an appropriate course of action to alleviate the problem. Corrective action to alleviate a problem may range from new controls implemented in manufacturing or test to a change in design or changing a part to one better suited to operational requirement. The generated corrective action should also be documented in detail so the action can be implemented and verified at the proper level. After a corrective action is implemented, it should also be monitored to assure that the corrective action has removed the failure causes and has not introduced new problems (Department of Defense, 2015).

This program provides guidelines for establishing a failure reporting system, thus its direct data usefulness is not available.

4.1.2.3 *Role of Industry*

Although there are not specific roles for industry members within this program, the requirements for a FRACAS normally will apply to the development of systems, equipment, and associated software subject to validation or full scale development (Department of Defense, 2015). Therefore, the guidelines provided under FRACAS are easily implemented by industry members as system developers for their own purposes. This early implementation of a FRACAS is important because corrective action options and flexibility are greatest during design evolution. Essentially, this program is one that has been developed by DoD for DoD. The earlier failure causes are identified, the easier it is to implement corrective actions. As the design matures, corrective actions still can be identified, but the options become limited and implementation is more difficult (Department of Defense, 2015).

While previous sections have highlighted the role of DoD as it relates to the FRACAS program, implementation guidelines of FRACAS take into account any external requirements by a customer or service provider, the characteristics of a product developed by the industry but used by DoD, and any marketplace constraints that may be present. Figure 3 below shows how a FRACAS solution should be reached, but also serves to illustrate how external aspects from industry members can play a role in the development of a FRACAS solution.

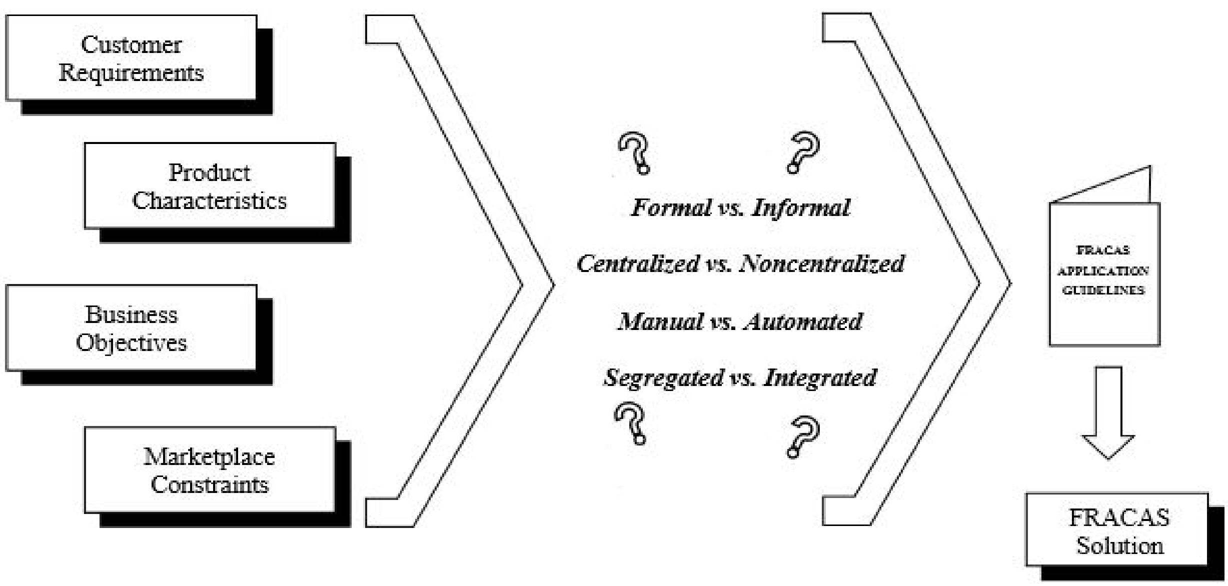


Figure 3: Defining the FRACAS Solution
(Reliability Analysis Center (RAC), 2008)

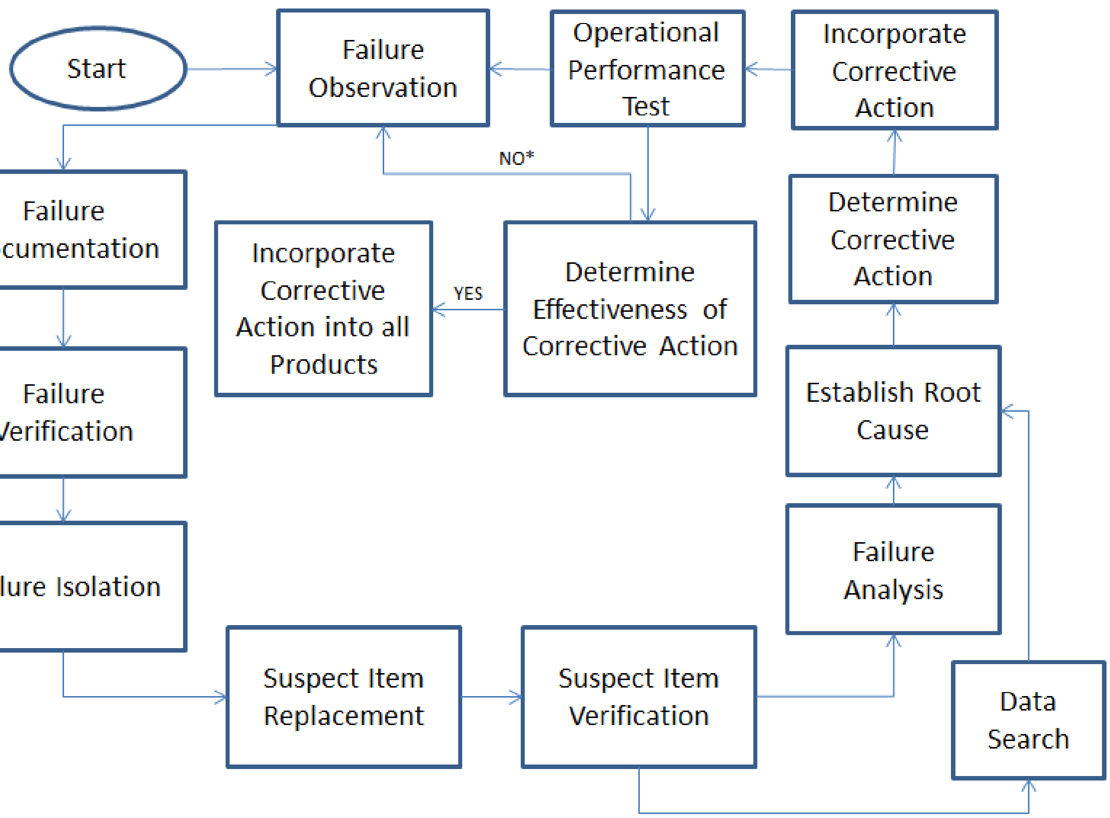
4.1.2.4 *Effectiveness*

A FRACAS will be effective only if the input data in reports documenting failures and faults is accurate. Essential inputs should document all conditions surrounding a failure or fault to facilitate cause determination. The failure documentation must provide information on who discovered the failure, what failed, where it failed, when it failed, and how future failures will be prevented. (Reliability Analysis Center (RAC), 2008).

This level of identification for the causes of a failure will help in developing the corrective action related to the failure. Both the comprehensive identification and the resulting corrective action are important facets to the primary objective of FRACAS: to provide a complete documentation of failures and faults and disseminate this information to allow the most effective corrective action can be implemented as quickly as possible (Reliability Analysis Center (RAC), 2008).

4.1.2.5 *Outcomes*

Figure 4 illustrates the overall closed-loop process of FRACAS. Once a failure is observed in one particular component or piece of equipment, it is assumed that it will perpetuate until a corrective action can be implemented for all the products that observed that failure. This is an important aspect of FRACAS because the guidelines for the corrective action are to be able to be implemented in all the products that would observe that failure. By implementing a corrective action to all products, even those that may not have exhibited a failure yet, the FRACAS process works towards eliminating the problem entirely, even before it could potentially become an issue again.



* If the corrective action is not effective then the proper root cause may not have been identified, and the failure will continue to occur

Figure 4: Failure Reporting and Corrective Action System
(Reliability Analysis Center (RAC), 2008)

4.1.2.6 *Data*

Figure 4 shows that data play an important role in the FRACAS process. As information is gathered on the "who, what, when, where, why, and how" of a failure, the data are then compared with other possible failures that are similar in an attempt to establish a root cause. In instances where previous data may not be available for a particular failure event, that failure event would then become its own unique data point and the FRACAS process would continue into the analysis of the failure event.

Unfortunately, the data gathered from FRACAS within the DoD is not readily available, and therefore a full analysis on the data collection, database management, and gaps could not be addressed for the purposes of this report.

4.1.2.7 *Liabilities*

While the DoD FRACAS is comprehensive, it is not a direct program to follow, but rather guidelines for improving failure reporting. Therefore, the DoD would have little direct liability. As a consequence, liability will fall upon those who intend to implement its recommendations. Military Standard 2155 (much of the FRACAS process in use today is based on this standard) was cancelled and superseded by Military Handbook 2155 in 1995; therefore mitigating the potential liabilities DoD assumed with the FRACAS process (EverySpec LLC, 2015).

4.1.2.8 *Application to BSEE*

Since its conception, DoD FRACAS has been used by all branches of DoD. Because it is recognized and broadly accepted, FRACAS has evolved into a useful tool for failure reporting. However, the DoD's application is unique in that it either owns the fielded assets or is paying for the system during development and acquisition. Since, BSEE does not own or procure the assets in the offshore industry, the direct applicability of FRACAS to BSEE is somewhat limited, but the overarching concepts and benefits of failure reporting are applicable. To further cement this approach, software technology is used by DoD and industry for reporting and tracking. Its closed-loop concept, similar to FRACAS, helps organizations track not only a particular purchased part or product but it is also used to manage the life cycle of a process, product or part. The software X-FRACAS is discussed in detail in subsequent sections of this report and could be a very useful process and tool for BSEE consideration.

4.1.3 Department of Transportation – Federal Highway Administration

The FHWA was formed in 1966, preceded by the Bureau of Public Roads, under the U.S. DOT. FHWA's main responsibilities include oversight of maintenance, construction and preservation highways, bridges and tunnels throughout the U.S. It is also charged with the task of improving safety and mobility, while encouraging innovation by conducting research (such as road condition and air quality) and providing technical assistance to state departments of transportation. FHWA uses the Highway Performance Monitoring System (HPMS) to identify and track failure issues within the national roads system (Federal Highway Administration, n.d.) (Federal Highway Administration, 2012).

4.1.3.1 *Information, Policies, and Procedures*

HPMS provides data that reflects the extent, condition, performance, use, and operating characteristics of the nation's highways. It was developed in 1978 as a national highway transportation system database. It includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and certain statewide summary information. HPMS replaced numerous uncoordinated annual State data reports as well as biennial special studies conducted by each State. These special studies had been conducted to support a 1965 congressional requirement that a report on the condition of the Nation's highway needs be submitted to Congress every two years (Federal Highway Administration, 2003).

The major purpose of HPMS is to support a data-driven decision process within FHWA, DOT, and Congress. HPMS data are used extensively for the analysis of highway system condition, performance, and investment needs that make up the biennial Condition and Performance Reports to Congress. These reports are used by Congress to establish both authorization and appropriation legislation, activities that ultimately determine the scope and size of the Federal-aid Highway Program, and determine the level of federal highway taxation.

The reports provide Congress with the state's rationale for requested Federal-aid Highway Program funding level. Congress, in turn, uses the findings from these reports to apportion Federal-aid funds back to the states under TEA-21. Both of these activities ultimately affect every state that contributes data to HPMS. Additionally, the Federal DOT uses report data to assess highway system performance under FHWA's strategic planning process. Pavement condition data, congestion-related data, and traffic data, combined with fatality and injury rates, are used extensively by the Administration to measure FHWA's and the state's progress in meeting the objectives embodied in the Vital Few (from the Pareto Principal/Six Sigma process stating that 80% of outcomes arise from 20% of cause variables), FHWA's Performance Plan, and other strategic goals (Federal Highway Administration, 2003).

4.1.3.2 *Elements, Best Practices, Lessons Learned*

HPMS is designed to evaluate road systems for safety and maintenance and does not address specific equipment used in detail. Our research did not discover significant information to indicate if FHWA's HPMS is used to provide feedback to OEMs to redesign or change equipment. FHWA admits, "all states employ data collection equipment by different manufacturers" (Federal Highway Administration, n.d.).

ABS Consulting identified the following example cases of OEM involvement as part of the HPMS process. The first example is of a case from the New Jersey Department of Transportation (NJDOT) where an OEM redesigned its equipment in response to HPMS failure reporting. NJDOT incorporated 3M's Microloop system to record the amount of automobiles that pass over a certain section of the road in an effort to determine the amount of traffic on the roadway. Although 3M's product worked correctly, NJDOT needed the Microloop specs changed in order to better record traffic-frequency data on the hour rather than on the 60-minute intervals for its specific HPMS. At NJDOT's request, 3M adjusted the Microloop equipment frequency setting to rectify the issue (Federal Highway Administration).

A second example comes from the Virginia Department of Transportation (VDOT) which works closely with the manufacturers of its traffic-counting equipment to improve the algorithms and technology used in VDOT's HPMS. VDOT and the manufacturers of its visual display components used to track the number of automobiles on the road together (i.e., PEEK) develop a classification table. VDOT requires the manufacturers to adjust the algorithms in their equipment to tightly match the classification tables. Such classifications include determining whether a four-axel count from the equipment is classified as two cars or one truck. "VDOT uses in-house software to cross check set-up parameters in counters to ensure that manufacturers correctly code in the required information" (Federal Highway Administration). Both the NJDOT and VDOT examples show how state DOT's HPMS requires OEMs to modify their design in order to collect more accurate data.

Additionally, ABS Consulting did find several mentions of manufacturers of equipment used for HPMS from FHWA guidelines. HPMS's Traffic Monitoring System for Highways uses Automatic Traffic Recorders (ATRs). According to FHWA Review Guidelines for HPMS in 2013, the Traffic Monitoring Program routinely checks the status of the program by asking such questions as are the "manufacturer's names of ATR systems (sensors and recorders) being used?" (Federal Highway Administration, 2013). The document's Pavement Data Review Guidelines also states that during the data collection process, "speed conditions specified by manufacturer, constant speeds within specified ranges" should be followed while measuring pavement roughness (Federal Highway Administration, 2013).

Since HPMS varies by state DOT, best practices are highly dynamic. State DOTs publish their own guidelines and best practices. These best practices are categorized as follows: Adjustment Factors and Growth Factors Calculation; Data Processing and Quality Control Procedures; Use of Intelligent Transportation System Data for Traffic Data Monitoring; Use of Innovative Contracting Practices; Ramp Balancing; Use of Safety Strategies; Use of Non-Intrusive Equipment; Equipment Selection, Calibration, and Maintenance; and Training and Guidelines for Traffic Monitoring Personnel. For example, the Maryland Department of Transportation (MDOT [MD]) and VDOT set best practices for Training Traffic Monitoring Personnel by outlining "detailed specifications and requirements for contractors to follow, including a review of data by a professional engineer" (Federal Highway Administration, 2004). If VDOT or MDOT (MD) find errors in short-term counts of roadway traffic, then they require the contractors to recount the section of highway. For Maintenance, Calibration, and Testing, the Michigan Department of Transportation (MDOT [MI]) downloads ATRs daily and then reviews them in week-long increments. Once an abnormality is discovered by the reviewed, a maintenance crew is sent to the site in question to check the device. MDOT (MI) requires that ATRs are polled daily for any communication issues and schedules traffic counts before or after highway construction.

State DOTs all provide several important best practices that can be imitated. Data collection is automated and reviewed for quality, best practices, and guidelines are shared among state DOTs and FHWA, proper training for staff and contractors is prioritized, equipment calibration and testing is implemented, and safety measures are clearly outlined and prioritized.

4.1.3.3 *Role of Industry*

FHWA's HPMS failure reporting system is used to evaluate the U.S. national highway system. While HPMS is used by the Federal and state governments to access and evaluate the nation's public road system and is not used by commercial or individual companies, all state DOTs use the guidelines set by FHWA to develop their own HPMS. According to FHWA, "while FHWA receives, screens, organizes, and uses these data, these are still the state's data and the state is ultimately responsible for the quality of the data" (Federal Highway Administration, 2003). The equipment used to collect data may vary from state to state, but the general principles of failure reporting for pavement, traffic, and safety conditions still remain constant.

Since state DOTs are considered the industry in terms of HPMS, they play a very important role for failure reporting. State DOTs are responsible for collecting highway, traffic and safety data, analyzing the data, creating guidelines and best practices, and sharing data with other state DOTs and FHWA. The state DOTs have a primary incentive to collect data and report the conditions of their highways to FHWA. By implementing HPMS, the state DOTs are able to justify to Congress areas of improvement that require Federal funding in the form of grants and appropriations.

4.1.3.4 *Effectiveness*

There are several ways in which DOT ensures this reporting system remains effective. The states use HPMS software to collect and submit reports to FHWA division office. When the state submits HPMS data to FHWA, the division is expected to assess the timeliness, completeness, and quality of the data. This is particularly true of those data items that pose the highest risk to FHWA and the state (e.g., the quality of the Interstate System lane-miles and traffic data that are used to apportion Interstate Maintenance funds to the states).

By November 1st of each year, FHWA division office must provide the results of an annual review of the state's HPMS program to FHWA headquarters, including a certification that the state's public road mileage data, highway miles traveled, and lane miles data are valid and suitable for use in apportionment of Federal aid highway funds (Federal Highway Administration, 2003).

FHWA Division office shares in the overall responsibility of providing HPMS data. The division office does this by:

1. Providing quality assurance of HPMS data;
2. Acting as a liaison between FHWA headquarters HPMS team and state DOTs in coordinating on reporting improvements;
3. Supporting and promoting the numerous beneficial uses of HPMS data;
4. Providing technical assistance to the states; and
5. Performing annual reviews.

The annual review of the state's HPMS data submittal conducted by each Division includes four components:

1. Program reviews of high risk subject areas;
2. Field inventory reviews;
3. Annual required reviews; and
4. Annual reporting (Federal Highway Administration, 2003).

FHWA's primer states, "HPMS serves needs of the states, Metropolitan Planning Organizations and local government and other customers in assessing highway condition, performance, air quality trends, and future investment requirements. Many states rely on traffic and travel data from HPMS to conduct air quality analyses and make assessments related to determining air quality conformity, and are now using the same analysis models used by FHWA to assess their own highway investment needs, the [Highway Economic Requirements System State Version]. As a result of these uses, states have an additional stake in assuring the completeness and quality of these data" (Federal Highway Administration, 2003).

Concerning incidents, HPMS gathers three types of rates: accident rates, injury rates, and fatality rates. These rates are recorded in incidents per 100 million vehicle miles traveled. According to David Leonard Lewis' *Road User and Mitigation Costs in Highway Pavement Projects*, "these rates, as employed by HPMS and the [Highway Economic Requirements System], do not take into account numerous other variable that affect highway safety. Other factors to consider include: pavement condition, weather and lighting, traffic congestion, traffic composition, traffic regulations, and driver characteristics (i.e., age, intoxication)" (Lewis, Road User and Mitigation Costs in Highway Pavement Projects. page 7).

4.1.3.5 *Outcomes*

FHWA utilizes a HPMS Program Activity Assessment form to evaluate the outcomes of HPMS reporting. This assessment also helps to identify key areas for improvement in terms of data quality and program efficiency. FHWA recommends that this assessment be performed by the state's DOT on a three-year cycle. According to FHWA's website, "the seven high priority activity areas are listed below:

- "Data Submittal (complete and timely);
- "State Planning and Research Work Program;
- "Quality Assurance;
- "Geographical Information System/Linear Referencing System Data Adequacy;
- "Traffic Data;
- "Pavement Data; and
- "Sample Adequacy" (Federal Highway Administration, 2013).[1]

While there is no OEM associated with this program, the following flow chart (Figure 5), from HPMS Review Guide on FHWS' website, depicts the review of HPMS reporting for traffic light systems.

[1] For a full copy of Status Report and HPMS Program Activity Assessment, refer to Appendix F.

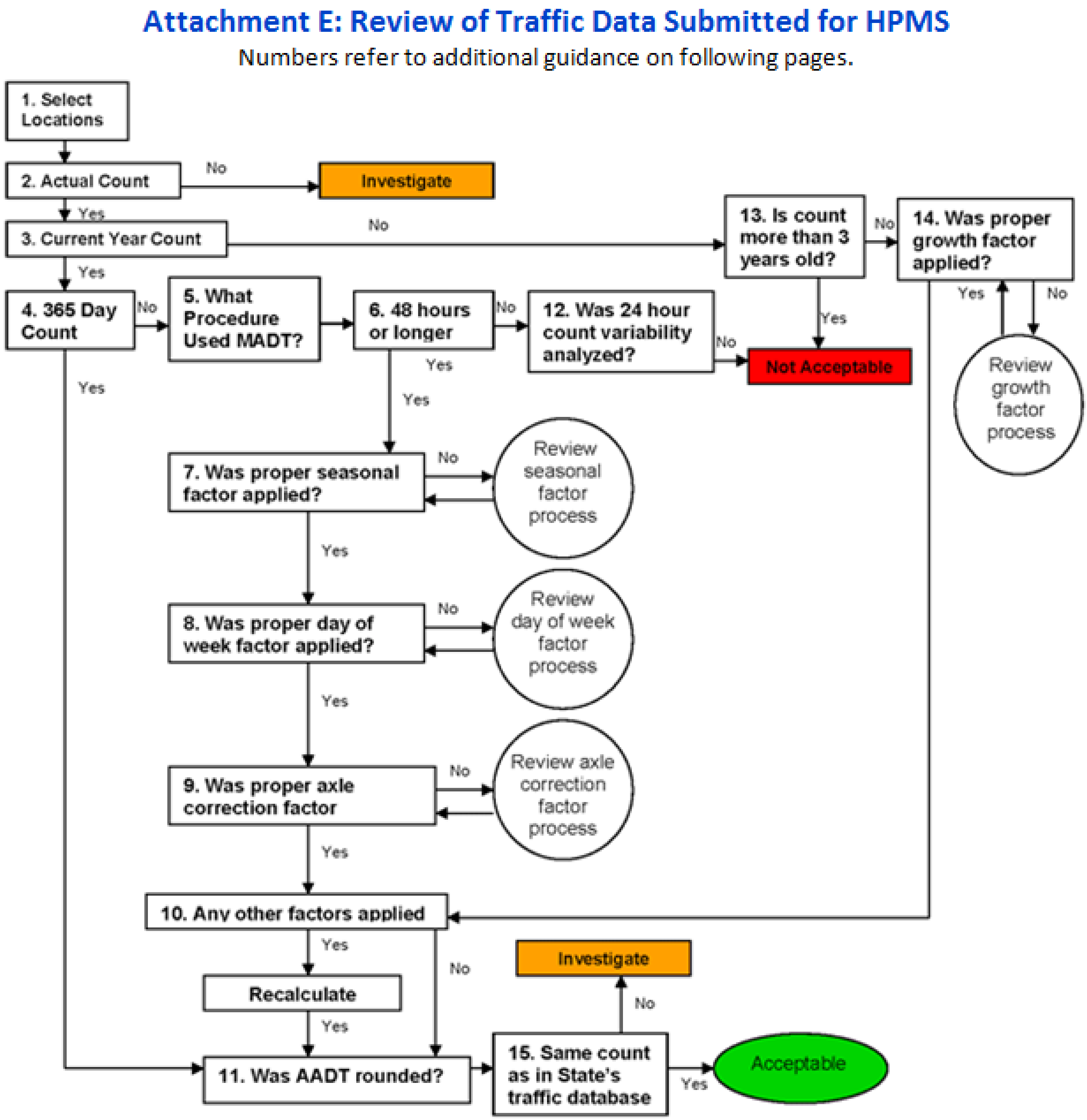


Figure 5: Process for Review of Traffic Data Submitted for HPMS
(Federal Highway Administration, 2013, p. 23)

4.1.3.6 *Data*

Data quality and assurance were identified as important issues. The ability to process and assess the quality of data from different data collection equipment efficiently was noted as a challenge, especially for high-volume routes. While states do not have a separate process for high-volume routes, they expect their processes to be robust enough to verify the validity of data for such traffic conditions (Federal Highway Administration, 2004).

Given the data-collection emphasis of HPMS, it is important that FHWA be able to demonstrate the program is being effectively carried out, and the projects being implemented are achieving results. The ultimate measure of the success of this program is a significant nationwide decline in the number of fatalities and serious injuries. To ensure the program is being implemented as intended and that it is achieving its purpose, an annual report on the Highway Safety Improvement Program implementation and effectiveness is required by 23 U.S.C. §148(g) and 23 CFR 924. Furthermore, state DOTs can demonstrate the success of the safety program through regular reporting. The states can use the report to communicate to others within their state about the importance of continuing to focus on improving highway safety (Federal Highway Administration, 2014).

4.1.3.7 *Liabilities*

Our research does not indicate that FHWA risks being held liable for any shortcomings from HPMS. HPMS's primary role is to collect and compile data from state DOTs. Since FHWA does not mandate guidelines, regulations, or best practices for the state DOTs to implement, FHWA has little control over how the state DOTs develop their individual failure reporting. State DOTs use a variety of equipment to measure safety, traffic, and pavement conditions. Since this type of failure reporting is decentralized and dynamic, our research indicates it would be difficult for FHWA to be held liable for any highway incidents or breaches of company proprietary data.

4.1.3.8 *Application to BSEE*

FHWA's HPMS contains several well-crafted practices that BSEE should consider for implementation. FHWA has an excellent system for data collection by coordinating with the various state DOTs. BSEE can also model its data collection and validation after HPMS by delegating data collection to the regions and coordinating requirements with the BSEE regions. BSEE could implement FHWA's HPMS Program Activity Assessment form in order to better evaluate the quality, timeliness, and completeness of data being submitted by the three regions.

BSEE could expand its data collection efforts regarding safety and environmental incidents beyond the regions by consulting with and gathering data from individual state regulators. As HPMS provides FHWA and DOT with crucial data to justify budgetary expenditures, BSEE can also use the aggregated data to determine which regions, states, or programs require additional funding from either within BSEE's current budget or request additional funding from Congress.

4.1.4 Department of Transportation – Pipeline and Hazardous Materials Safety Administration

PHMSA is a U.S. DOT agency that develops and enforces regulations for the safe, reliable, and environmentally sound operation of the nation's 2.6 million mile pipeline transportation system and the nearly 1 million daily shipments of hazardous materials by land, sea, and air. PHMSA comprises two safety offices, the Office of Pipeline Safety and the Office of Hazardous Materials Safety. PHMSA's mission is to protect people and the environment from the risks inherent in transportation of hazardous materials – by pipeline, truck and other modes of transportation. PHMSA was created under the

Norman Y. Mineta Research and Special Programs Improvement Act (P.L. 108-426) of 2004 (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015).

PHMSA's failure reporting regulations date back to the early 2000s for Hazardous Materials and Gas transportation companies. The recent history of PHMSA's failure reporting guidelines for hazardous materials dates to 2001 and to 2004 for Gas transportation companies. PHMSA regulation of Gas distribution became effective as of 2010.

4.1.4.1 *Information, Policies, and Procedures*

PHMSA regulates the transportation of oil and other petrochemicals via pipeline and other means. PHMSA has a set of statutory mandatory failure reporting requirements for their regulated industry. For PHMSA, there are two primary sets of reporting requirements: pipelines and hazardous materials.

PHMSA regulations indicate that a report is required for all failures regardless of the material composition, type of failure,[2] manufacturer, or size of the fitting. Spills or accidents involving hazardous liquid, carbon dioxide (CO_2), gas distribution systems, mechanical fitting failure, gas transmission and gathering systems and liquefied natural gas all have separate reporting forms. These rules indicate that any leak which involves an existing or probable hazard to persons or property and requires an immediate repair or continuous action until the conditions are no longer hazardous must be reported.

PHMSA Pipeline Reporting Requirements

For Pipelines, PHMSA has three main reporting requirements. First, within two hours of an identified incident pipeline operators are expected to notify the National Response Center via telephone. Second, within 30 days operators are expected to submit an incident report to PHMSA. Third, operators must submit an annual report by March 15th of the following year (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015).[3]

Federal law (49 CFR Parts 191, 192) mandates that gas distribution pipeline operators submit an annual report which lists all failures involving a mechanical fitting, regardless of material (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015). Annual Reports are required to be filed by March 15th of the following year using PHMSA form F-7100.

Regardless of the type of liquid the pipeline contains or the purpose of the pipeline, the information in the accident reports is similar. This typically includes:

1. "Operator information: name of company, etc.;

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[2] These may include failures in the body of the mechanical fitting, failures in the joints between the fitting and the pipe, seal leakage associated with the fitting, and partial or complete separation of the fitting from the pipe.

[3] Pipeline accidents generally are reported to PHMSA when one of three things occurs: (1) a fatality, (2) an injury or (3) $50,000 or more in property damage.

2. “Accident information: location, time and area, terrain, pipeline bridge area, pipeline crossing area, origin (intra or interstate);
3. “National Response Center ID Number;
4. “Spill characteristics: volume, intentionality, type of commodity released (natural gas, crude oil, etc.);
5. “Volume of commodity recovered;
6. “Causality information: deaths of operator employees, emergency responders, bystanders, etc., injuries;
7. “Pipeline shutdown information;
8. “Commodity ignition/explosion;
9. “Numbers of general public evacuated;
10. “On/off shore location of accident;
11. “Pipeline identification information: name, line, segment ID;
12. “Potentially exposed population: population density of local area, possibility of a high consequence area being impacted;
13. “Estimated property damage;
14. “Operating company information;
15. “Pipeline operating pressure information: maximum operating pressure, pressure at time of accident, low pressure operation;
16. “Valve and manufacturing specifications: type of valve used to isolate release source, pipe manufacturing specifications, pipe thickness, type of weld used in pipe;
17. “Function of pipeline systems;
18. “SCADA and leak detection system information;
19. “Initial accident identification method and circumstances;
20. “Operating company drug and alcohol testing;
21. “Pipe maintenance history;
22. “Accident cause information: Whether evidence of natural force damage, excavation damage, outside force damage, material failure of pipe or weld, equipment failure or incorrect operation;
23. “Narrative description of the accident; and
24. “Declarative signature of operating company executive” (U.S. Department of Transportation - Hazardous Materials and Safety Administration, 2015).[4]

PHMSA Hazardous Materials Reporting Requirements

PHMSA hazardous materials reporting is essentially the same as pipeline incident reporting. There are three steps involved in reporting hazardous materials. First, Federal regulations require an immediate telephonic report (within 12 hours) to the National Response Center in the event of a spill. Second,

[4] For details on PMHSA pipeline reporting see http://www.phmsa.dot.gov/pipeline/library/forms.

some types of hazmat incidents require a written report within 30 days of incident. Third, a follow up written report is also required within one year of the incident, based on certain circumstances (U.S. Department of Transportation - Hazardous Materials and Safety Administration, 2015). Information included in hazardous materials reporting is generally based on Form F 5800.1 and contains the following data:

1. "Report type
2. "Incident information (date, time, location, mode of transport [rail, truck, etc.], carrier, shipper, origin, destination, name of hazardous material, technical trade name, shipping circumstances (whether labeled as hazardous waste or not)
3. "Packaging information (packaging type [tank car vs. motor vehicle])
4. "Failure information (what, how and cause of failure), whether valve failed or not
5. "Packaging identification markings
6. "Packaging capacity (amount, capacity, number in shipment)
7. "Packaging construction details (manufacturer, serial number, design pressure, shell thickness, head thickness)
8. "Radioactive packaging materials
9. "Consequences information (emergency response, results of incident, damages [in $ dollars], hazardous material contributions to fatalities/injuries/evacuation, closure of major transport artery, material transported involved in crash or derailment)
10. "Air Incident Information: Shipment on aircraft, location where incident occurred, shipment processing phase
11. "Description of event/failure: narrative description including photographs and diagrams showing event/failure, failure duration data;
12. "Recommendations/actions taken to prevent occurrence; and
13. "Contact information: name, telephone number, email, etc." (U.S. Department of Transportation - Hazardous Materials and Safety Administration, 2015).

PHMSA mandates that reporting be completed by industry via the PHMSA designed and maintained internet data access portal.[5] PHMSA mandates that unless other dispensation is granted, all failure reporting is to be completed via this portal. The portal contains login access for both pipeline and hazardous materials transportation services and is continually updated and improved as feedback from industry becomes available.

4.1.4.2 *Elements, Best Practices, Lessons Learned*

While PMHSA was created in 2004, current PHMSA regulations have been in place since 2001. In the pipeline industry the safe management of pipelines is called Pipeline Integrity Management (PIM). As defined by PHMSA, PIM is a broadly encompassing subject which involves a number of activities that should be performed to ensure that spills do not occur (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015). From the PHMSA webpage:

[5] See https://portal.phmsa.dot.gov/portal

> Integrity Management takes a broader view, encompassing the environment, as well as pipeline. Pipeline operators are required to know more about the areas their pipeline traverses; the nature of the population in the area; the existence of environmentally sensitive areas near the pipeline. Fundamentally, Integrity Management seeks to understand the potential consequences of failure of a specific pipeline in a particular area. It sets priorities for inspection and operations and maintenance based on whether people, property or the environment might be at risk should a pipeline failure occur (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015).

For PHMSA, Integrity Management (IM) regulations fall under three distinct areas: hazardous liquids, gas transmission, and gas distribution. IM regulations were developed during the last decade and utilize a risk based approach. In general, the IM approaches taken by PHMSA differ slightly depending on whether gas is transmitted or distributed. For hazardous liquids and gas transmission, PHMSA IM regulations are known as the "Liquid IM Rule" and the "Gas IM Rule."

Adopted in 2000 and 2003 respectively the "Liquid IM Rule" and the "Gas IM Rule" are regulatory mandates which call for a number of actions to ensure safety (U.S. Department of Transportation - Pipeline and Hazardous Materials and Safety Administration, 2015) (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015). Briefly summarized these include:

1. Mandating that industry actors maintain and update a comprehensive risk management plan;
2. Defining terms, baselines, change management and communication plans;
3. Specifying risk assessment methodologies;
4. Identifying risk and outlining risk mitigation strategies;
5. Outlining inspection protocols; and
6. Mandating performance measurement reporting (U.S. Department of Transportation - Pipeline and Hazardous Materials and Safety Administration, 2015) (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015).

For liquid IM, operators must implement these measures on pipelines that could affect certain areas (known as High Consequence Areas [HCAs]). HCAs for liquid lines include commercially navigable waterways, certain populated areas, and drinking water and ecological resource areas (Susan Olenchuk, 2012).

For gas IM, operators must implement heightened measures on pipelines that fall within HCAs. An HCA for a gas pipeline is an area near the pipeline that contains several buildings or areas intended for human occupancy (Susan Olenchuk, 2012).

The Liquid IM Rule and the Gas IM Rule are distinguished from the manner in which PHMSA regulates gas distribution. PHMSA regulations on gas distribution were developed in consultation with industry (U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration, 2015). Gas distribution regulations are a significantly higher level and contain a greater degree of flexibility than the Liquid and Gas IM Rules (U.S. Department of Transportation - Hazardous Materials and Safety Administration, 2015). For example, the IM guidelines for gas distribution only require operators implement an IM program which has the following elements:

1. Knowledge;
2. Identify Threats;
3. Evaluate and Rank Risks;
4. Identify and Implement Measures to Address Risks;
5. Measure Performance, Monitor Results, and Evaluate Effectiveness;
6. Periodically Evaluate and Improve Program; and
7. Report Results (U.S. Department of Transportation - Hazardous Materials and Safety Administration, 2015).

Performance measures in reporting primarily include only information regarding leaks/failures – proscriptive language regarding broader metrics, mitigation strategies and risk assessment protocols is lacking. The PHMSA webpage lists the reason for the more relaxed restriction as being due to “significant differences in system design and local conditions affecting distribution pipeline safety” which “preclude applying the same tools and management practices as were used for transmission pipeline systems” (U.S. Department of Transportation - Pipeline Safety and Hazardous Materials Safety Administration, 2015). In addition, PHMSA documentation also suggests that many gas distribution operators are in urban areas and fall under the jurisdiction of state-level regulatory agencies.

4.1.4.3 *Role of Industry*

PHMSA is closely tied with the pipeline and hazardous materials industry. Since its inception in 2004, the administration regulates individual companies that own and operate pipelines, as well as private shipping companies that transport hazardous materials. Pipeline operators are comprised of petroleum, natural gas, and other chemical companies that transport hazardous materials via pipeline. PHMSA regulates operators of various forms of transportation, including rail, air, boat, and highway.

Operators must submit Hazmat Incident Reports and Pipeline Accident Reports to PHMSA. According to PHMSA’s website, “PHMSA's 139 federal inspection and enforcement staff and over 300 state inspectors are responsible for regulating nearly 3,000 companies that operate 2.6 million miles of pipelines, 118 liquefied natural gas plants, and 6,970 hazardous liquid breakout tanks. Through PHMSA oversight programs, serious pipeline incidents have decreased by 37% since 2009” (Pipeline and Hazardous Materials Safety Administration, n.d.).

While failure reporting data is fed to PHMSA, the feedback in place is the subsequent communication to owners and operators. PHMSA asserts that, “pipeline operators must know, understand, and manage the risks associated with their own pipeline facilities,” knowledge that can be gained in two ways (Pipeline and Hazardous Materials Safety Administration, n.d.). The first is for pipeline operators to conduct their own internal safety training, equipment inspections, and emergency procedure development in addition to PHMSA inspections; a sentiment encouraged by DOT (Pipeline and

Hazardous Materials Safety Administration, n.d.). The second would be owners and operators taking proactive measures in understanding the data and outcomes of PHMSA efforts.

For industry members to understand the data and outcomes of PHMSA efforts, this would not only provide the operators with significant information in ensuring sound practices, but also promote a line of communication that would allow PHMSA to become aware of industry needs before a significant incident would arise. Furthermore, industry members would have a greater understanding of how regulations and standards are developed by PHMSA and why they are necessary; with data to back up the efforts.

4.1.4.4 *Effectiveness*

PHMSA's organizational goals are clearly tied to failure report data (e.g., PHMSA's 2016 safety goals are to reduce the number of pipeline accidents involving death or major injury to 26-37 per year). By 2016, the agency aims to reduce the number of hazardous materials incidents involving death or major injury to between 21 to 32 per year (U.S. Department of Transportation - Pipeline Safety and Hazardous Materials Safety Administration, 2015). These metrics (accidents and hazardous materials incidents) are a core part of PHMSA failure reporting.

For PHMSA, effectiveness is defined in terms of safety. Failure reporting regulations are viewed as comprehensive or effective to the degree that they reduce incidents of hazardous materials or pipeline spillage. Although hazardous materials and pipeline spillage incidents have decreased over the past 30 years, some areas of PHMSA regulation (such as gas distribution regulations) have not necessarily shown safety improvements. PHMSA is currently seeking new regulatory authority governing rail transportation of hazardous materials (Bradley, 2015) (Devaney, 2014).

Data quality is vital to the effectiveness of failure reporting. The integrity of failure reporting data is evaluated once submitted. Reports are submitted online and are immediately compiled into a database. First, each record is reviewed for consistency. During this process, they examine the form for personally identifiable information, business rule inconsistencies, invalid dates, and invalid commodities (by cross-checking with the commodities in the database) (U.S. Department of Transportation, 2015). Second, PHMSA staff use an automated web crawling system to check for unreported incidents, which they then include in their internal databases. In addition, they match incidents up with the telephonic record from the National Response Center. If there is no match, records are flagged as being unreported. They wait 60 days and attempt again to pair the unreported incidents to the telephonic records in case of a delay in case a record had not been inputted into the system.

In general, the DOT estimates that underreporting is at 20%, with slightly higher underreporting and incompletion rates among highway and motor carrier accidents (Transportation Research Board of the National Academies, 2009).

To determine the extent of PHMSA failure reporting requirements, ABS Consulting reviewed PHMSA failure reporting Forms F-7100 and F 5800.1 – data requirements for pipelines and hazmat transportation (U.S. Department of Transportation, 2004).

For Form F 5800.1 – Hazardous Materials Transportation Incident Report - the following data components address environmental issues (U.S. Department of Transportation, 2004):

1. "Consequences – whether the environment was impacted yes/no.
2. "Consequences – Total cost, remediation cost (in $ dollars)" (U.S. Department of Transportation, 2004).

For Form F-7100 – Petrochemical Incident Report – the following data components address environmental issues (U.S. Department of Transportation, 2015):

1. "Property damage – cost of environmental remediation (in $ dollars).
2. "Environmental cause of cracking – stress (yes/no), hydrogen (yes/no), sulfide (yes/no).
3. "Natural force damage contributed to incident (specify, whether earth movement, heavy rains/flood, lightning, temperature, frozen components, high winds or other natural force damage).
4. "Natural force damage caused as part of an extreme weather event.
5. "Wildlife impact (yes/no), type of wildlife impacted, fish/aquatic (yes/no), birds (yes/no), and terrestrial (yes/no).
6. "Soil contamination (yes/no).
7. "Anticipated remediation, (specify all that apply: Surface water, groundwater, soil, vegetation, wildlife).
8. "Water contamination (yes, no), specify all that apply: Ocean/seawater, surface, groundwater, drinking water (private well/public water intake).
9. "Estimated amount reaching water (in barrels).
10. "Name of body of water impacted by spill.
11. "Whether the release impacted an Ecological Unusually Sensitive Area defined in the Operators IM Program (yes/no).
12. "Earth movement not due to heavy rains or floods (specify all that apply, earthquake, substance, landslide, washout/scouring, flotation, mudslide, lighting [direct hit vs. secondary impact], temperature, thermal stress or frost heave, high winds, other natural force damage) (U.S. Department of Transportation, 2015).

To generate a rough approximation of PHMSA analysis requirements, most of PHMSA's published analysis were simple descriptive statistics including summary counts and trend data, suggesting their analysis requirements are focused on simple, but robust, administrative metrics.

4.1.4.5 *Outcomes*

PHMSA's regulatory outcomes are measured through the use of failure reporting statistics. The agency retains and publishes a comprehensive set of hazardous materials and pipeline safety data (U.S. Department of Transportations Pipeline and Hazardous Materials Safety Administration, 2015). In the past, this data has assisted in identifying gaps in regulatory coverage. For example, in 2011 PHMSA analyzed serious pipeline incidents (those involving deaths and injuries) and found that accidents were far more likely in gas distribution pipelines than in gas transmission pipelines. These findings made it clear that a significant reduction in the rate of serious pipeline incidents could not be achieved without addressing gas distribution pipelines, which lead to a series of conversations with industry and ultimately to revisions in regulations regarding Distribution Integrity Management Program (DIMP) of distribution pipelines (Administration, 2011).

Both the Liquid IM Rule and the Gas IM Rule have formal procedures for failure reporting which are documented in diagrams below. For the Liquid IM Rule, failure reporting is outlined in step two of a three-part process. For focus, only step 2 is shown (Figure 6 and Figure 7). It should be noted that for the Liquid IM Rule, OEMs are not included in the reporting structure.

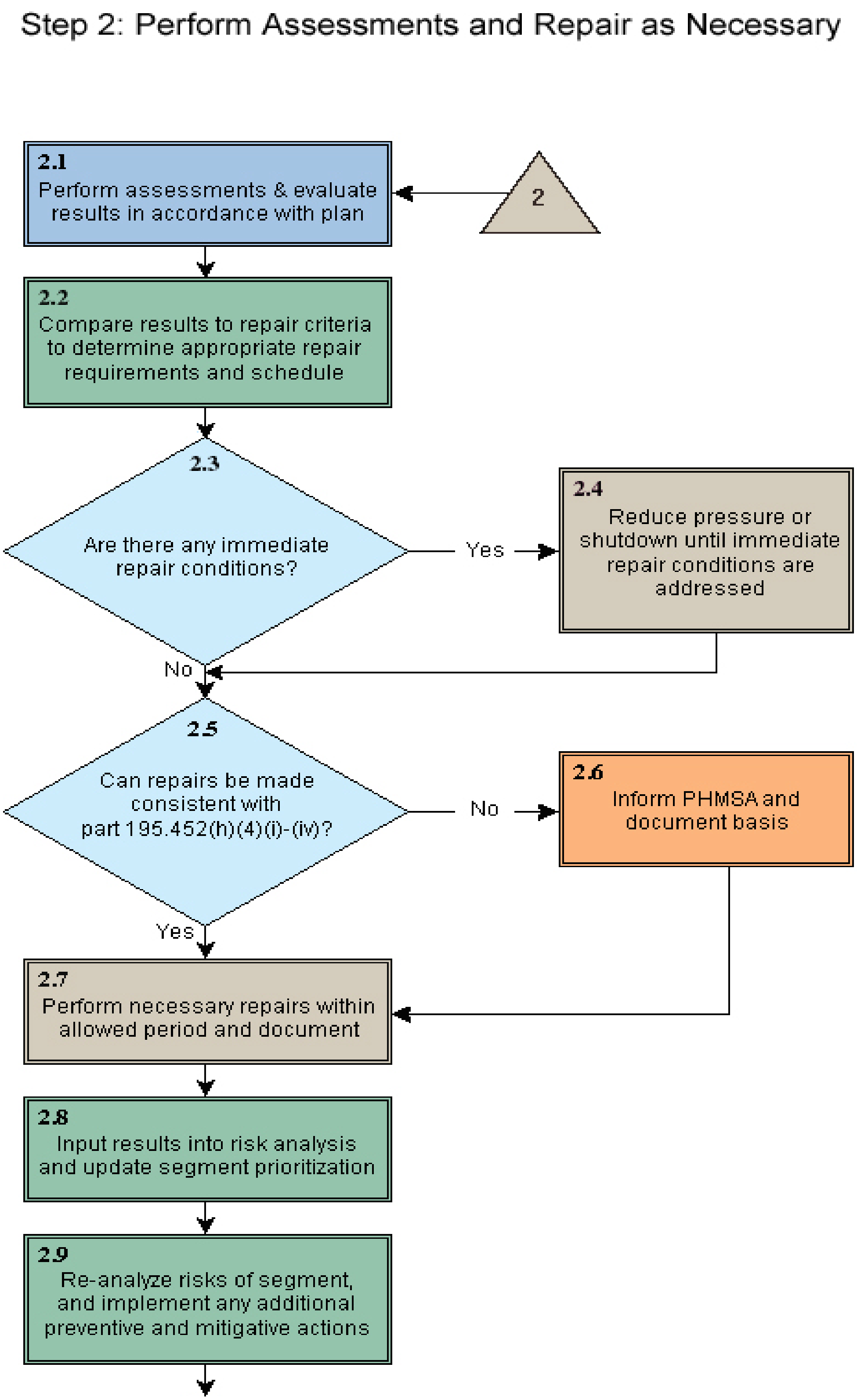

Figure 6: U.S. DOT PHMSA Failure Reporting Requirements for Hazardous Materials (1 of 2)
(U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration)

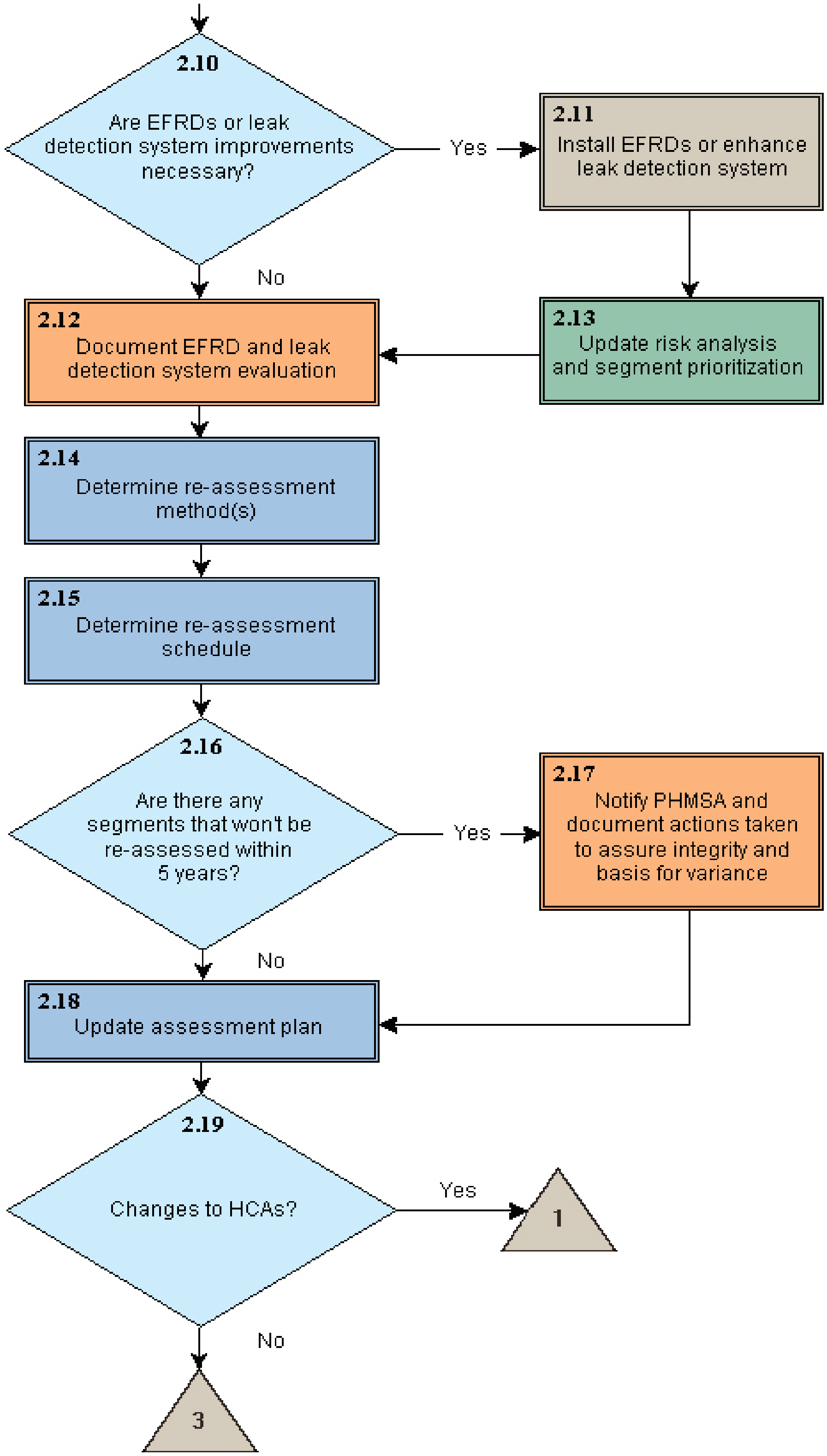

Figure 7: U.S. DOT PHMSA Failure Reporting Requirements for Hazardous Materials (2 of 2)
(U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration)

For the Gas IM Rule, failure reporting is outlined in Step 4 of a six-part process. For focus, only Step 4 is shown (Figure 8). As with the Liquid IM Rule, OEMs are not included.

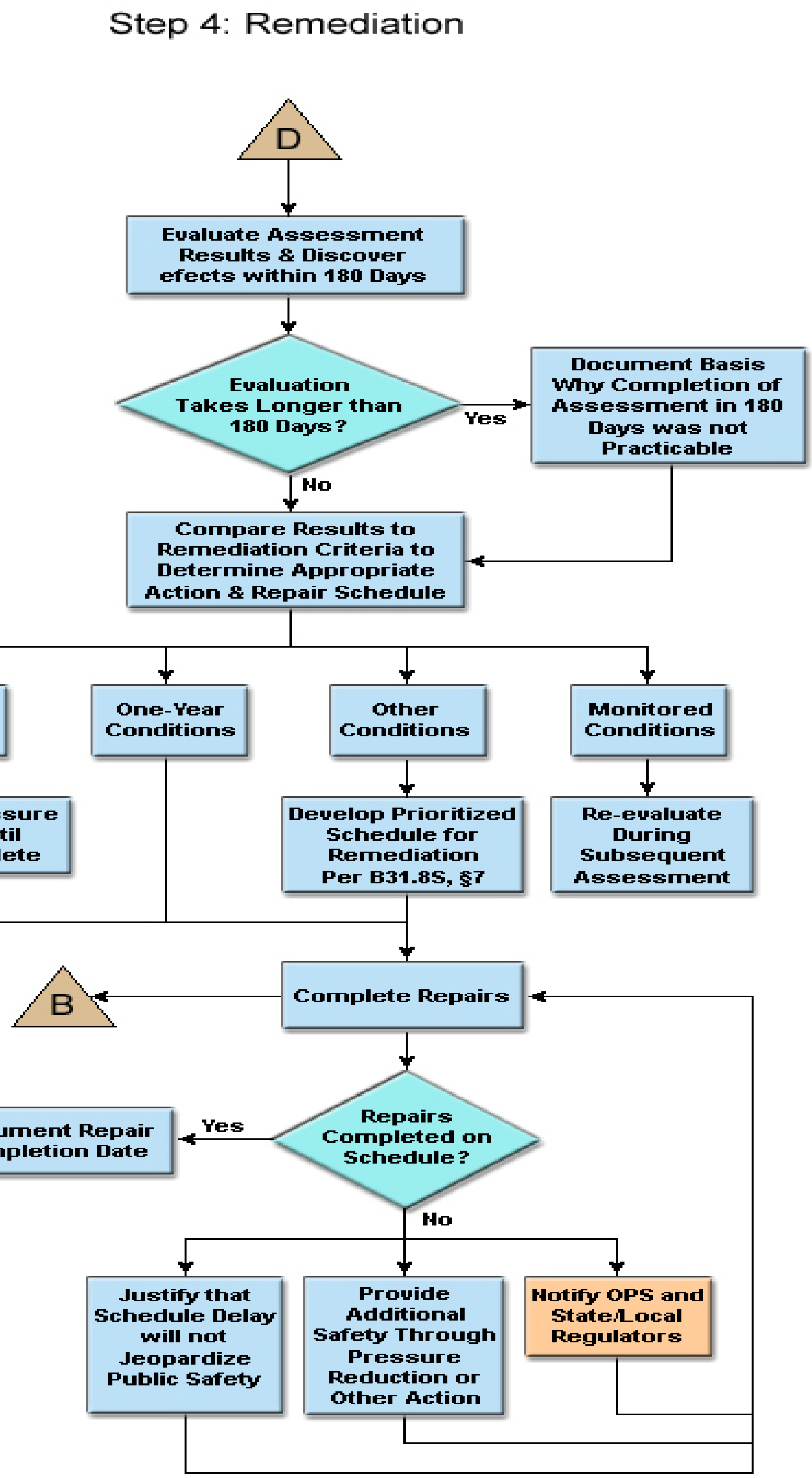

Figure 8: U.S. DOT PHMSA Failure Reporting Procedures for Gas Transmission
(U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration)

4.1.4.6 *Data*

PHMSA's regulated industry appears to be taking a passive stance toward agency-issued regulation (Curry, 2015) (Fuetsch, 2015). This stance appears to be driven largely by PHMSA inaction. The Association of American Railroads petitioned PHMSA to conduct a rulemaking on new tank-car design standards, which did not see regulatory action until 2013, when a train transporting crude oil ignited in 2013, killing 47 people (Fuetsch, 2015).

Serious pipeline failures involving injury, deaths or substantial property losses have been declining since 2009, which PHMSA attributes to improved enforcement (U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, 2014). While more aggressive enforcement is certainly an important element in declining serious incidents, other factors such as improved materials and manufacturing, as well as changing regulatory scope and shifting public sentiment likely also play a role.

4.1.4.7 *Liabilities*

PHMSA was established to promote safe practices by inspecting pipelines and enforcing component and reporting compliance. While a majority of the legal liability for pipeline failures rests on the regulated industry, PHMSA still shares some risk.

PHMSA is responsible for quality control of the failure reporting data submitted by the industry. As discussed in Section 4.1.4.4, PHMSA must validate industry failure reporting data by checking for commodity, date, and business rule inconsistencies. With an estimated 20% of pipeline and hazardous material failures being underreported, PHMSA is also tasked with combing additional databases to find unreported failures. If PHMSA fails to properly validate industry data or find unreported failure data, then PHMSA's official data may be questioned by the private businesses, domestic and international government agencies, academic institutes and a variety of other organizations that rely on PHMSA for valid, official industry data. Negligence in PHMSA's quality assurance process could lead to possible lawsuits or discredit its reputation as a trusted data source.

In addition, PHMSA role in providing hazmat and pipeline regulations and guidance for the industry increases its liability should a failure occur while complying with PHMSA regulation. Since the industry regards PHMSA as the authority to set a standard of regulations, if the industry follows the regulations but still incurs an accident that results in injury, PHMSA could be held liable if the regulation was deemed inadequate or inappropriate for the purpose.

If the pipeline operator fails to abide by PHMSA regulations and incurs a pipeline failure that results in environmental damage or public safety risk, the company, not PHMSA, will burden the liability. This scenario has occurred many times, with companies being held liable for hazardous material releases that occurred while operating outside of PHMSA regulations.

4.1.4.8 *Application to BSEE*

PHMSA failure reporting requirements suggests at least two areas of application for BSEE. First, BSEE should consider adopting a mandatory internet-based submission to increase accountability. All failure reports can be time-stamped, providing BSEE with a basis for both evaluating and enforcing timeliness requirements. Second, if BSEE adopts an online reporting portal with standardized reporting forms, BSEE could benefit from an increase in data reliability and uniformity, thereby enhancing the ability of BSEE program analysts to monitor industry failure reporting trends.

4.1.5 Nuclear Regulatory Commission

The NRC is an independent agency of the U.S. Government, established by the Energy Reorganization Act of 1974, and began operations on 19 January 1975. As one of two successor agencies to the U.S. Atomic Energy Commission, the NRC's role is to protect public health and safety related to nuclear energy. It oversees reactor safety and security, reactor licensing and renewal, licensing of radioactive materials, radionuclide safety, and decommissioning including spent fuel management including storage, security, recycling, and disposal.

While this section deals primarily with the NRC's Licensee Event Reporting (LER) system, NRC also employs an internationally used reporting system, the Web Based Incident Reporting System, (WB IRS) or International Reporting System (IRS) for Operating Excellence for short. The WB IRS is managed and maintained by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development and acts as a platform by which thirty-one participating countries exchange experience to improve the safety of nuclear power plants by submitting event reports on unusual events considered important for safety (International Atomic Energy Agency, 2015).

While NRC does not own or maintain the WB IRS, NRC is a participating organization. For example, NRC has historically submitted summaries of problems with U.S.-based domestic nuclear facilities to WB IRS (Nuclear Regulatory Commission , 2009) (Nuclear Regulatory Commission, 2008)

4.1.5.1 *Information, Policies, and Procedures*

LERs are part of the non-proprietary Sequence Coding and Search System (SCSS) developed by NRC. Broadly speaking, NRC requires operators of nuclear power plants to submit an LER "when conditions occur in a nuclear power plants that are beyond its technical specifications" (Nuclear Regulatory Commission, 2011). Since its implementation in 1980, the LER system has accumulated approximately 52,000 submissions from nuclear power plant operators under NRC jurisdiction (Nuclear Regulatory Commission, 2011). These submissions are compiled and provided on the NRC website, updated monthly.

Both NRC regulations 10 CFR 50.73 and 50.72 state that LER reporting should occur any time:

- "The condition of the nuclear power plant, including its principal safety barriers, being seriously degraded; or
- The nuclear power plant being in an unanalyzed condition that significantly degraded plant safety" (Nuclear Regulatory Commission, 2014).

While the regulation for submitting an LER may seem quite broad, NRC wishes to avert under-reporting for failures by including a wide range of failure-related incidents, not only ones that result in personnel injury or equipment damage. A failure for a nuclear power plant could cause catastrophic damage to the surrounding community as well as to the safety reputation of the nuclear industry. NRC's LER system is not only a way for plant operators to report a failure that has already occurred, but also a way for the nuclear industry and other plant operators to take preventative measures to increase safety and efficiency. By studying LER submissions, nuclear plant operators and industry can learn from the risks and failures of other plants.

NRC also outlines specifically what information must be included in an LER, per regulation 10CFR 50.73 (Nuclear Regulatory Commission, 2014). It states that an LER should contain:

1) "A brief abstract describing the major occurrences during the event, including all component or system failures that contributed to the event and significant corrective action taken or planned to prevent recurrence.
2) "A clear, specific, narrative description of what occurred… The narrative description must include the following specific information as appropriate for the particular event:
   - "Plant operating conditions before the event.
   - "Status of structures, components, or systems that was inoperable at the start of the event and that contributed to the event.
   - "Dates and approximate times of occurrences.
   - "The cause of each component or system failure or personnel error, if known.
   - "The failure mode, mechanism, and effect of each failed component, if known.
     - "For failures of components with multiple functions, include a list of systems or secondary functions that were also affected.
     - "For failure that rendered a train of a safety system inoperable, an estimate of the elapsed time from the discovery of the failure until the train was returned to service.
   - "The method of discovery of each component or system failure or procedural error.
   - "Automatically and manually initiated safety system responses
   - "The manufacturer and model number (or other identification) of each component that failed during the event.
3) "An assessment of the safety consequences and implications of the event. This assessment must include:
   - "The availability of systems or components that could have performed the same function as the components and systems that failed during the event.
   - "For events that occurred when the reactor was shut down, the availability of systems or components that are needed to shut down the reactor and maintain safe shutdown conditions, remove residual heat, control the release of radioactive material, or mitigate the consequences of an accident.
4) "A description of any corrective actions planned as a result of the event, including those to reduce the probability of similar events occurring in the future.

5) “Reference to any previous similar events at the same plant that are known to the licensee.
6) “The name and telephone number of a person within the licensee's organization who is knowledgeable about the event and can provide additional information concerning the event and the plant's characteristics” (Nuclear Regulatory Commission, 2014).

LERs are a successful method of failure reporting for the NRC. The nuclear industry and plant operators have an extensive library of failure reports at their disposal on the NRC website. They can use the information from LERs to update their own equipment specifications, emergency procedures, safety and operational training, and risk-mitigation plans. It is important to note that some of the requested information listed above for an LER contains sensitive information for the plant operator, such as a point of contact and manufacturer information for equipment that failed. A plant operator may be leery of providing failure information since it could affect its current and future business development, reputation, and invite lawsuits. To encourage failure reporting, NRC makes all LERs anonymous before making the information publicly available.

4.1.5.2 *Elements, Best Practices, Lessons Learned*

NRC designed the LER to collect consistent data per regulation 10CFR 50.73. As described in Section 4.1.5.1 above, NRC requires specific information for each LER form to be submitted. This ensures the nuclear industry can properly understand how and why the failure occurred in addition to what corrective actions were taken. The industry can then compare the LER information to its own nuclear facilities and be prepared to either better prevent the failure from occurring or apply similar corrective actions should the failure occur. In addition, the NRC does an excellent job in encouraging failure reporting by editing the submitted LER to make it anonymous. Before submitting an LER, the licensee is notified on NRC’s website that sensitive information provided will be made anonymous.

Our research uncovered instances where an OEM changed its equipment specifications based on an incident reported in an LER. As part of NRC’s LER Form 366, the reporting nuclear facility must provide information under a “Corrective Actions Taken” section. LER 2011-005, concerning a broken Service Water System (SWS) pump shaft coupling that resulted in a 72-hour limiting condition for operation, provides one such example of how the data gleaned from the LER has been used to change equipment specifications. According to the Corrective Actions Taken, “A new design specification using 1 7-4PH SS for the material of the SWS pumps shaft couplings was developed and approved for all three SWS pumps. The new design specification for the coupling material was changed in order to minimize susceptibility to Intergranular Stress Corrosion Cracking. The 4165S shaft couplings on P-7A and P-7B were replaced with the 17-4PH SS design” (Appendix B) (Florida Power & Light Company, St Lucie Nuclear Plant, 2005).

4.1.5.3 *Role of Industry*

The nuclear industry plays an important role in providing NRC with failure reporting information. The portion of the nuclear industry that communicates most with NRC is the group of nuclear power plant operators. By registering as a member with the NRC, these operators commit to submit accurate and timely failure reports via LERs in an effort to make the nuclear industry a safer and more efficient environment for both employees and the surrounding public.

We assume that all adhere to the 10 CFR 50.73 regulations on LER submission, and utilize NRC Form 366 when compiling LERs. It is unknown how long each plant operator has been registered with the NRC.

4.1.5.4 *Effectiveness*

NRC evaluates the effectiveness of its failure reporting in several ways. A publicly accessible NRC dataset built off of LER information pertains to significant plant fires that occurred from 1990-2009. Stating that "the purpose of this study data is to provide a metric with which to assess the effectiveness of improvements to the U.S. NRC's fire protection regulations," NRC therefore uses LER data as a tool to help measure their own regulatory effectiveness (Nuclear Regulatory Commission, 2010).

NRC's research division uses LER data in trending studies, albeit it suffers from issues with funding. The level of reporting done by the research branch of the NRC is directly proportional to its level of funding. As a consequence, this branch's overall contributions to NRC regulations are inconsistent (Liming J. , NRC Regulatory Q&A Call, 2015).

As mentioned earlier, LERs are non-proprietary reports that are accessible to the general public through Licensee Event Report Search (LERSearch). LERs are also not anonymous, as the company name, a point of contact, and the plant's location are all given in a completed LER. LER data can be used as a way to assess the effectiveness of certain NRC regulations, most likely through a recorded drop in the frequency and/or severity of failure or safety related incidents.

Given the nature of nuclear power production, equipment malfunctions are viewed in light of how greatly they threaten the safety of the plant and its surroundings, particularly in regards to the release of radioactive material into the environment. LERs do not record events that are classified as emergencies, but in a scenario where an emergency event does occur at a plant, a broad variety of agencies may become involved in the situation (Nuclear Regulatory Commission, 2014).

As mentioned in the Task 2 Report: LCM Systems, the data requirements for a LER comprise of:

- "Plant conditions;
- "Description of problem;
    - "Background;
    - "Event and analysis;
- "Method of Discovery;
- "Cause of problem;
- "Safety consequences;
- "Corrective actions; and
- "Past similar events" (Nuclear Regulatory Commission, 2014).

LERSearch specifically is an interactive online repository in which any public user can search LERs based on "a variety of criteria including date of occurrence, nuclear power plant name, plant-operating mode, reactor type, regional location, and keywords" (Nuclear Regulatory Commission). In addition to providing the general populace with information concerning the maintenance of "adequate levels of safety and protection," LERs are also used by NRC to develop its Common Cause Failure Database (CCFDB). These reporting systems correspond to non-emergency events in which threats to human safety could potentially be realized (Nuclear Regulatory Commission, 2013).

The most practical function of LERs is to provide input data for the CCFDB. The CCFDB draws from three systems, two of which provide the same information on different time frames. The two complementary systems are the Equipment Performance and Information Exchange (EPIX) and the Nuclear Plan Reliability Data System (NPRDS). Both contain proprietary data on component failures. EPIX contains such data from 1997 to present, while NPRDS contains data from 1980 to 1996 (Nuclear Regulatory Commission, 2013)). It is not known why NRC transitioned to EPIX, or if any substantial differences in data collection exist between EPIX and NPRDS.

The third system is the SCSS. The SCSS contains some, but not all, of the LER data generated by licensees. Therefore, it is reasonable to conclude that the SCSS contains strictly non-proprietary data. NRC explicitly states that EPIX and NPRDS are proprietary in nature. However, no such statements are made regarding SCSS, even though it is unknown at this time if SCSS also contains non-LER data (Nuclear Regulatory Commission, 2013).

In order for a particular LER's data to be included in the CCFDB, it must be classified as a Common Cause Failure event. Specifically, NRC defines Common Cause Failure events as "component failures that satisfy four criteria" (Nuclear Regulatory Commission, 2007):

1) "Two or more individual components fail, are degraded (including failures during demand or in-service testing), or have deficiencies that would result in component failures if a demand signal had been received.
2) "Components fail within a selected period of time such that success of the probabilistic risk assessment mission would be uncertain.
3) "Components fail because of a single shared cause and coupling mechanism.
4) "Components fail within the established component boundary" (Nuclear Regulatory Commission, 2007).

NRC asserts that "all LERs submitted by licensees are reviewed for events applicable to the CCFDB as well as other ongoing programs at the Idaho National Laboratory pertaining to plant performance indicators, system reliability studies, and initiating event studies" (Nuclear Regulatory Commission, 2007, p. xi).

The CCFDB suffers from a lack of consistency for how it updates and inputs information. Highly technical in nature, the CCFDB is based around probabilistic risk assessments that utilize conditional probabilities to predict plant component failures. These assessments help establish a significance determination process that is mandated under NRC regulations for all plants (Liming J. , NRC Regulatory Q&A Call, 2015). See Figure 9 for the CCF data analysis process.

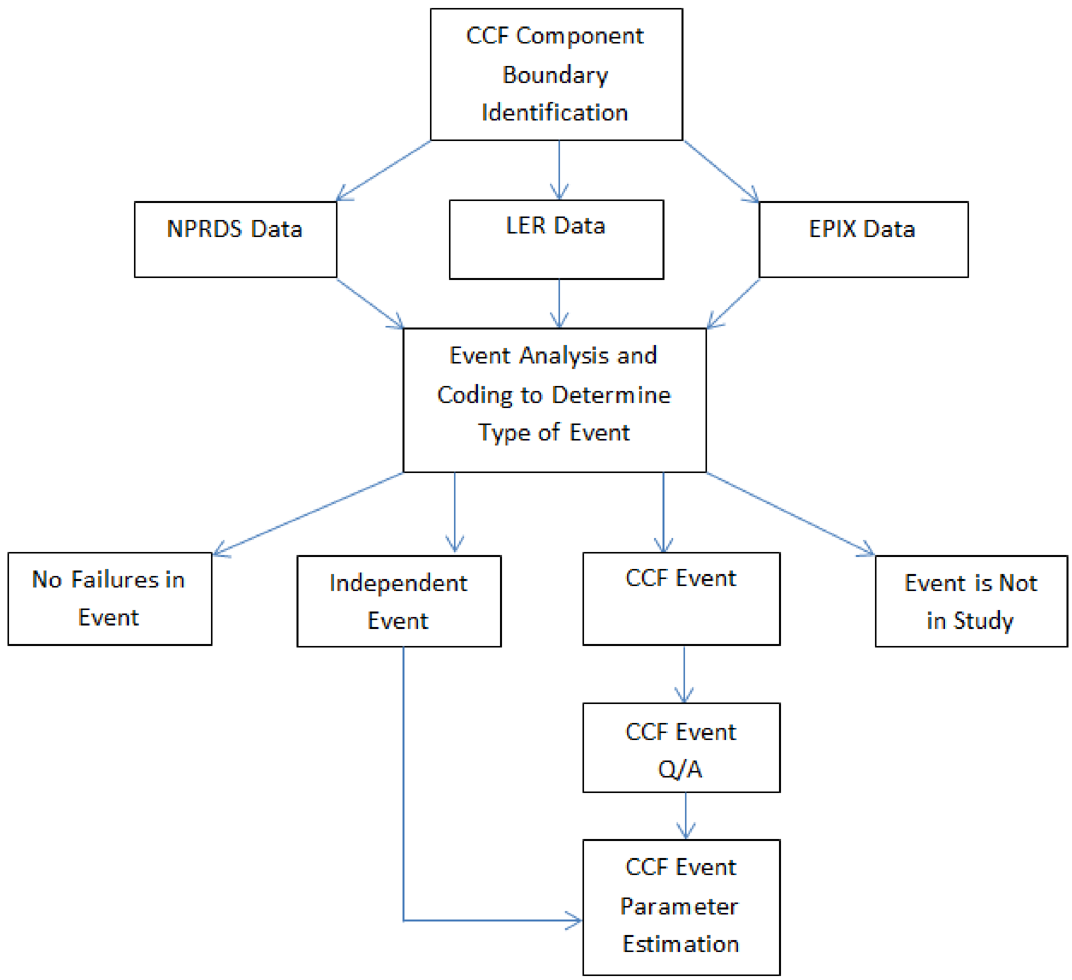

Figure 9: CCF Data Analysis Process
(Nuclear Regulatory Commission, 2007, p. xii)

Reports to NRC fall under two categories: Immediate Event Notifications and LERs. Immediate Event Notifications correspond to both emergency and non-emergency alerts and events, while LERs correspond to only non-emergency events. Under NRC reporting guidelines, a non-emergency Immediate Event Notification does not always require a subsequent LER, and, alternatively, an LER must not always be preceded by a non-emergency Immediate Event Notification.[6]

NRC's main guidelines for LERs fall under 10 CFR 50.73, whereas Immediate Event Notifications fall under 10 CFR 50.72. While there is extensive overlap between the two in terms of conditions warranting

[6] Emergency class Immediate Event Notifications go to the Emergency Response Data System. All non-emergency Event notifications can be accessed by the public at: http://www.nrc.gov/reading-rm/doc-collections/event-status/event/

a notification or report, a primary difference between 50.72 and 50.73 is that the former is written in the present tense, indicating that NRC is notified as the situation unfolds, and the latter is written in the past tense, indicating that a LER should be a retrospective summary and analysis of an event that has already been resolved (Nuclear Regulatory Commission, 2014) (Nuclear Regulatory Commission, 2014).

Correspondence between non-emergency Immediate Event Notifications and LERs is to reduce the amount of paperwork for the licensee, the depth of explanation and scenarios NRC gives to distinguish between all possible cases can be convoluted. For example, a non-emergency Immediate Event Notification is required when a plant shutdown is initiated, but an LER is only required if the shutdown process is completed (Nuclear Regulatory Commission, 2014) (Nuclear Regulatory Commission, 2014).

The Immediate Event Notification form, NRC 361, is only a two page document asking for operation information, event classification, and radiological releases (Nuclear Regulatory Commission, 2000). The LER form is comparable in length, about five pages fully completed. Refer to Appendix B for an example of a completed LER.

In a separate document compiled explicitly for the purpose of distinguishing between the 50.72 and 50.73 reporting requirements, NRC states that:

> The level of judgment for reporting an event or condition under this criterion is a reasonable expectation of preventing fulfillment of a safety function… If the event or condition could have prevented fulfillment of the safety function at the time of discovery an [Emergency Notification System] notification is required. If it could have prevented fulfillment of the safety function at any time within three years of the date of discovery a LER is required (Nuclear Regulatory Commission, 2000).

Moreover, the level of judgment specifically falls on the plant's engineering staff, as "the application of these and other reporting criteria involves the use of engineering judgment." In addition, "the licensee may also use engineering judgment to decide when personnel actions could have prevented fulfillment of a safety function."

The form required to submit a LER, NRC form 366, can be obtained and filled out through NRC's website by any public user at no cost (Nuclear Regulatory Commission, 2014).

4.1.5.5 *Outcomes*

NRC does track certain statistics within the nuclear industry, such as the frequency and severity of failure incidents at nuclear facilities. A severe failure would be one that causes radioactive materials to be released to either the plant staff or surrounding community. More minor incidents may be the shutdown of a plant reactor or other critical component due to a failure in the system. ABS Consulting assumes that the NRC is tracking these trends and updating failure reporting procedures to account for any shortcomings based on the data analyzed across the industry.

Although our research did not reveal significant information on how OEMs are involved in the LER process, Figure 10 charts the process of how an event is reported and how that information can be utilized by both NRC and its registered operators through the CCFDB.

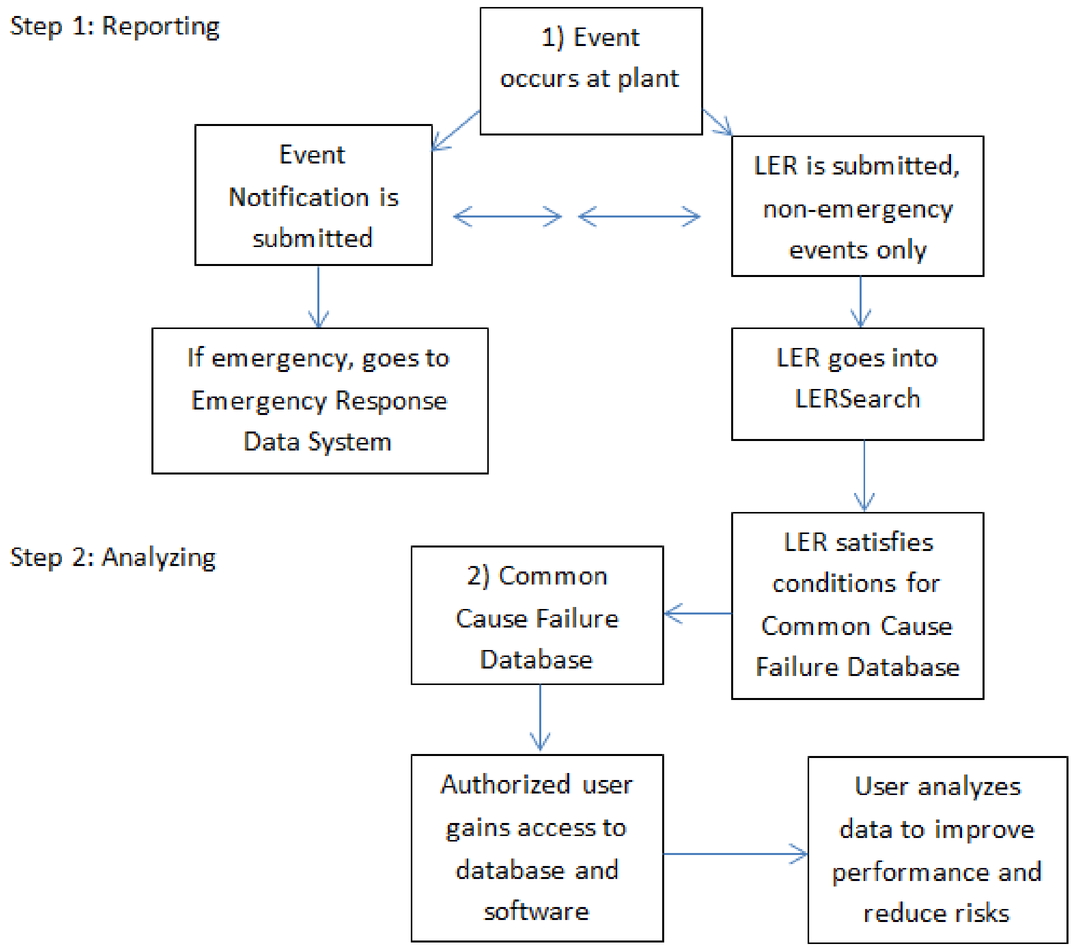

Figure 10: LER Event Reporting Process

4.1.5.6 *Data*

As mentioned in Section 4.1.5.5, there is a publicly accessible data set on significant plant fires over the course of about twenty years. LER data were the sole source from which this data set was compiled. The NRC used these data as a measure "to assess the effectiveness of improvements to the U.S. NRC's fire protection regulations" (Nuclear Regulatory Commission, 2010).[7]

ABS Consulting identified instances where OEMs used information gleaned from an LER to improve the design or specifications for its product. OEMs can analyze LERs over multiple years to identify a trend in

[7] The dataset itself can be accessed through: http://catalog.data.gov/dataset/fire-event-data-from-licensee-event-reports.

faulty components to improve reliability using advanced prediction methods and specifying the level of reliability (Science Applications International Corporation, 1986).

4.1.5.7 *Liabilities*

NRC places the legal liability upon the independent power plant operators (licensees) and requires the operator to submit an LER in the event of a failure incident. It is unknown at this time what the consequences are for a plant operator if 10 CFR 50.73 requirements are not met.

Although not required by the Price-Anderson Act, NRC regulations require licensees to maintain a minimum of $1.06 billion in onsite property insurance at each reactor site accident (U.S. Nuclear Regulatory Commission, 2014). NRC added this requirement after the Three Mile Island accident out of concern that licensees may be unable to cover onsite cleanup costs resulting from a nuclear accident. This insurance is required to cover the licensee's obligation to stabilize and decontaminate the reactor and site after an accident (U.S. Nuclear Regulatory Commission, 2014).

4.1.5.8 *Application to BSEE*

The complexity of NRC's failure reporting procedures is instructive yet challenging to apply to BSEE's organization. There are different requirements depending on the type of failure (i.e., simple, common cause or emergency), all of which are backed up by an extensive set of documentation rooted in an exhaustive set of laws (Nuclear Regulatory Commission, 2015). Accordingly, rules for failure reporting are not immediately understandable to persons unfamiliar with NRC or the nuclear industry. While this regulatory complexity is well suited to a complex industry, it does make it more challenging for third party reviewers to quickly evaluate the state of failures across the entire nuclear industry. Accordingly, the lesson from NRC's failure reporting systems appears to be that BSEE should balance the need for comprehensiveness with appropriate levels of simplicity and transparency.

While it is somewhat confusing to determine when an immediate Event Notification versus an LER is warranted, the way in which the NRC utilizes LER data makes this system extremely useful. LERSearch is a useful feature that allows for public scrutiny, as well as the CCFDB.

The complementary components to the CCFDB, of proprietary and non-proprietary data, help to ensure the development of a comprehensive dataset to analyze. NRC also has checks in place to prevent duplicate data from the respective sources migrating into the CCFDB. By offering its registered operator's access to the CCFDB along with software for analysis, NRC does appear to be doing an effective job helping industry improve performance and eliminate common repeated mistakes.

By reviewing its own external methods of improvement on industry with the same data used for internal improvement, subsequent policies can reflect observed needs that the operators already agree with. Overall, the LER system and the CCFDB are entities BSEE should try to replicate in order to develop a process to develop regulations with industry.

4.2 International Agencies

The information in this sub-section describes the data collected for the following international organizations: New Zealand (Department of Labor), Norway (Petroleum Safety Authority [PSA]), and two organization from the United Kingdom (UK Health and Safety Executive [HSE] and Oil and Gas UK).

4.2.1 New Zealand, Department of Labor

The New Zealand Department of Labor, now known as the Ministry of Business, Innovation and Employment, is responsible for developing policy and regulations and delivering services and advice in support of the growth of New Zealand. New Zealand does not have a failure reporting system; rather, they have a Safety Management System (SMS) that covers both LCM and failure reporting processes. The Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) was enacted on 5 June 2013.

4.2.1.1 *Information, Policies, and Procedures*

The New Zealand regulations do not identify, mention, require, or recommend, in any way, the use of commercially available failure reporting systems, programs or software. Duty Holders and/or Operators are responsible for failure reporting. The facility Safety Case would specifically address any failure reporting program in place, how information would be gathered, how the information would be disseminated and if a commercial software reporting system would be used.

All facilities are required to develop and maintain a SMS. Under the requirements of the Health and Safety in Employment Act (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208), Schedule 4, the facilities must identify a description, with scale diagrams, of:

- (i) In relation to a production installation, the intended location of the installation:
- (ii) The main and secondary structure of the installation and its materials:
- (iii) The plant and equipment of the installation:
- (iv) The layout and configuration of its plant:
- (v) Any designated hazardous areas:
- (vi) In relation to a production installation, the connections to any pipeline or installation:
- (vii) In relation to a production installation, any wells to be connected to the installation… (New Zealand Government Parlimentary Council Office, 2013).

4.2.1.2 *Elements, Best Practices, Lessons Learned*

No specific failure reporting system or process is outlined in the regulatory requirements under New Zealand law. Duty holders and/or operators are required to develop a comprehensive Safety Case and ensure the Safety Case describes in detail those requirements outlined in the regulations. Under Schedule 1 of the Health and Safety in Employment Act requirements for Standards and Procedures, there are specific requirements for the operator to describe the process for any changes in the risk profile of operations of the facility. The operator must identify, assess, and describe how they will reduce any risk to the lowest possible level. Under Schedule 1 of the Health and Safety in Employment Act requirements for performance monitoring, there are requirements for the operator to have arrangements in place to periodically assess the installations integrity. Under Schedule 4 of the Health and Safety in Employment Act requirements for the installation, operators are required to include in their Safety Case, a description, with scale diagrams, of their facility as they apply to:

- (i) A production installation, the intended location of the installation;
- (ii) The main and secondary structure of the installation and its materials;
- (iii) The plant and equipment of the installation;
- (iv) The layout and configuration of its plant;
- (v) Any designated hazardous areas;
- (vi) A production installation, the connections to any pipeline or installation;
- (vii) A production installation, any wells to be connected to the installation (New Zealand Government Parlimentary Council Office, 2013).

Under Schedule 4 of the Health and Safety in Employment Act requirements for the Management of Major Accident Hazards, the operators are required to conduct a risk assessment and describe in detail how they will address the elimination, prevention, reduction and mitigation control measures that have been or will be taken to reduce risk. Operators must also describe in detail performance standards for these control measures.

Though no specific failure reporting system is prescribed in the New Zealand regulation, duty holders or operators would be responsible for and specifically detail how they would report failure data to manufacturers that could lead to design changes or equipment specification changes. Under New Zealand law, this information would be managed and maintained by the duty holders and/or operators of the facilities.

4.2.1.3 *Role of Industry*

The role of industry is to develop a SMS as required by New Zealand Health and Safety in Employment Act regulations. Companies requesting to conduct business within the New Zealand territory must also develop a Safety Case. Development of the Safety Case is the responsibility of the Duty Holder and/or Operator, and if a failure reporting system is used, it must be clearly defined how this program will be managed. Though there is no specific regulatory requirement to develop a failure reporting system by name, Health and Safety in Employment Act regulations do contain certain reporting requirements. The Safety Case must be approved by the New Zealand Government prior to an organization conducting business.

It is the Duty Holder's and/or Operator's responsibility to ensure all operations specifically follow the requirements described in the facilities Safety Case and report all deviations as may be required by regulations. Reportable deviations may include: serious injuries or fatalities, major accidents or major environmental damage.

The primary role of industry is to ensure all regulatory requirements are met and all health, safety and environmental laws are followed. In the event of serious accidents or significant environmental damage, it is the Duty Holder and operator's responsibility to report these incidents as required under New

Zealand laws and regulations. Ultimately, Duty Holder's and Operator's role is to provide a safe and environmentally friendly work environment for employees.

4.2.1.4 *Statutory/Regulatory Elements*

Under the Health and Safety in Employment Act regulations Schedule 1, the SMS must provide an overview of Performance Monitoring. This overview must cover:

(i) The arrangements in place for monitoring performance in relation to the management of major accident hazards and other workplace hazards;

(ii) The arrangements for reporting, analyzing, and learning from incidents and work-related illness;

(iii) The arrangements in place for independent and competent persons to audit the management of major accident hazards and other workplace hazards;

(iv) The arrangements in place for independent and competent persons to verify that safety-critical elements remain effective;

(v) The arrangements in place for the periodic assessment of the installation's integrity;

(vi) The arrangements for reviewing the effectiveness and suitability of the major accident policy and safety management system. (New Zealand Government Parlimentary Council Office, 2013)

4.2.1.5 *Effectiveness*

Duty Holders and/or Operators are required under the New Zealand Health and Safety in Employment Act regulations to specifically identify how they track and report failures. Under these requirements, if the operator does not follow the described failure reporting procedures as defined in the facility Safety Case they will be subject to penalty under New Zealand law. No specific data is available to determine the specific effectiveness of this process. Facilities continue to effectively operate in New Zealand, so it can be assumed the process and the facilities performance of failure reporting is satisfactory.

The design, structure, data reporting, and equipment covered by the SMS is solely the responsibility of the specific facility and their operations. No data or specific reporting information is available under the New Zealand program.

4.2.1.6 *Outcomes*

No specific data is available to determine the specific effectiveness of this process. Facilities continue to effectively operate in New Zealand so it can be assumed the process and the facilities performance of failure reporting is satisfactory. If this program is incorporated into an organization Safety Case, the Duty Holder and/or Operator are responsible to ensure the program is followed as described in the Safety Case.

4.2.1.7 *Data*

The New Zealand regulations do not specify how an operation tracks OEM and service provider utilization. If an organization has a program to cover these issues, it must be specifically addressed and the process clearly defined in the Safety Case developed by the Duty Holder and/or Operator. It would then be the responsibility of the Duty Holder and/or Operator to make reports on product assessments and improvements and to track the program's effectiveness.

4.2.1.8 *Liabilities*

The Duty Holder and/or Operators are responsible for developing the facility Safety Case and all responsibilities in ensuring the Safety Case is specifically followed. It can be assumed that all legal liability then rests with the Duty Holder and/or Operator.

4.2.1.9 *Application to BSEE*

The New Zealand Government's Health and Safety in Employment Act (Petroleum Exploration and Extraction) Regulations 2013 (SR 2013/208) are written and developed in such a way which requires industry to ensure they cover all required elements of the regulations. Each facility must develop and receive government approval of a Safety Case in order to begin construction of and conduct operations on any facility.

The burden of responsibility and the specifics of how a facility meets the required elements of the regulations are placed solely with the requesting industry organization so long as the Safety Case meets the requirements of the regulations and is approved by the New Zealand government. How the elements of the Safety Case are specifically developed and prosecuted is the responsibility of the industry organization requesting authorization to build and operate a facility.

BSEE could use a similar model and develop regulations specifically tasking industry organizations to take the responsibility of developing their operations in such a way that meets the needs of the industry organization but also falls within the requirements of the regulations. The structure of the New Zealand regulations places the burden of developing, operating and reporting of a facility on the specific organization requesting start-up and operations. While this would not adequately address the legal liabilities within the U.S., it would provide additional man-power from industry to develop these first steps in regulatory development and standards development.

4.2.2 Norway, Petroleum Safety Authority

Norway's PSA is an independent government regulator with responsibility for safety, emergency preparedness, and the working environment in the Norwegian Petroleum Industry. The regulations and supervisory system designed by the PSA are implemented with the goal of enhancing the awareness of companies so they will assume total responsibility of their operations, ultimately improving the health, safety and the environment of the offshore petroleum industry and the land-based facilities subject to the PSA's supervisory authority (Petroleum Safety Authority, 2014).

4.2.2.1 *Information, Policies, and Procedures*

PSA failure reporting regulations are broad and comprehensive in scope. For failure reporting data, the PSA mandates that a wide variety of information be submitted by the petrochemical operator. This includes:

- Reports about situation of hazard and accident

- Damage to load-bearing structures/pipelines – goes to Corrosion and Damage (CODAM) database
- Manned underwater operations – goes to Diving Related Accidents (DSYS) database
- Drilling reports – through Daily/Common Drilling Reporting System (DDRS/CDRS)
- Hours worked
- Electrical accidents involving personal injury
- Report on occupational accident
- Occupational illness

As noted above, damage reports and incidents occurring on load-bearing structures and pipelines go to the CODAM database. While the reports are only available in Norwegian, the CODAM database provides users with overviews of all "reported damage and incidents for structures, pipelines, and risers." (Petroleum Safety Authority, 2013) Moreover, all reported incidents occurring during manned underwater operations are sent to the DSYS database, which collects all data associated with diving incidents. From a report that utilized statistical analyses on data from 1985-2012, the PSA observed that only two minor injuries occurred during manned underwater operations, in addition to one near-miss hazardous situation (Petroleum Safety Authority, 2013).

Additionally, Daily Drilling reports (also referred to as Common Drilling reports) are submitted to the PSA daily through the DDRS/CDRS. The PSA has been collecting such reports since 1984. The specific content expected in each report could only be found in Norwegian (Petroleum Safety Authority, 2015).

The PSA RNNP project (trends in risk level in the petroleum activity) was initiated in 1999 to develop and apply a tool to measure health, safety and environmental conditions on the Norwegian Continental Shelf (NCS). The aim is to identify trends or development in the risk level over time. As stated in the Task 2 report on LCM, PSA's supervision is risk-based, rather than having a scheduled or systematic approach. Results reported from RNNP are used to identify areas involving the highest level of risk, and thereby the priorities for surveillance.

Results are presented in annual reports; therefore, trends are identified on an annual basis. The main report is published every April. Totaling more than 400 pages, this comprehensive document comprises two sections in Norwegian covering the NCS and (since 2006) land-based plants, respectively. A summary report of almost 50 pages is published for the NCS in both Norwegian and English. RNNP risk data related to acute oil and chemical spills are provided in a separate report in Norwegian every fall. RNNP annual reports are freely accessible at PSA's home pages.[8]

RNNP includes both qualitative and quantitative indicators, as well as both lagging and leading indicators. To elaborate on the latter, the PSA interprets leading indicators as "information regarding the current situation, which can affect future performance" (Petroleum Safety Authority, 2012). Explicit examples of leading indicators as applied to well-control systems are based on defined risk levels of

[8] The English summary report can be found at http://www.psa.no/list-of-reports/category913.html.

certain events such as hydrocarbon influx, shallow gas flow, and shallow water flow (Petroleum Safety Authority, 2012). Lagging indicators, on the other hand, "usually refer to accidents, injuries, or fatality rates," and, broadly speaking, data that can only be obtained after an event has occurred (Petroleum Safety Authority, 2012).

Qualitative indicators are exemplified by questionnaire-based surveys which are performed every two years. The questionnaire has varied over the years, but is primarily for personnel conditions and in the 2013 report covered the following topics: demographics, climate, experience of accident risk, recreation conditions, working environment, ability to work, health, sickness absence, sleep, rest, and working hours (Petroleum Safety Authority Norway, 2013).

Quantitative indicators are limited to major accidents, which are here defined as an accident caused by faults in one or more of the system's built-in safety and preparedness barriers (Petroleum Safety Authority Norway, 2013). Data are collected for 12 categories:

1. Unignited hydrocarbon leak;
2. Ignited hydrocarbon leak;
3. Kick/loss of well control;
4. Fire/explosion, excluding ignited hydrocarbon leak;
5. Vessel on collision course;
6. Drifting object/vessel on collision course;
7. Collision with field related traffic;
8. Structural damage;
9. Leak from subsea installation;
10. Damage to subsea installation;
11. Evacuation (precautionary/emergency); and
12. Helicopter incident/accident on/near installation/field (Petroleum Safety Authority Norway, 2013).

These data are further detailed and contain information on leak size, areas, severity, installation types, and other factors.

RNNP does not aim to establish component failure rates. Results are not reported per component and cannot be used for prediction or input data to quantitative analyses since each installation is different. However, a separate section on barriers where failures are recorded per barrier element, such as Downhole Safety Valve, Blowout Preventer (BOP), Pressure Safety Valve, and other equipment. Only safety and environmentally critical events are included; production critical failures are not included.

The main purpose is to identify trends on the NCS with respect to HSE. In addition, RNNP reports maintenance activities in terms of total Preventative and Corrective Maintenance backlog, personnel injuries, work environment factors and falling objects.

The PSA recommends the License2Share (L2S) program run by the Exploration and Production Information Management Association (EPIM) for the submission of required materials and information.

According to the PSA, L2S "is a joint solution for processes related to license administration and official correspondence between the petroleum industry and the authorities." No estimates of cost could be obtained via EPIM's website (EPIM, 2011). L2S functions specifically to assist joint venture parties "with disparate processes and data from various sources and applications" by bringing all this information "into a single collaboration platform" (License2Share, 2015).

4.2.2.2 *Elements, Best Practices, Lessons Learned*

In addition to the broad reporting policies mentioned earlier, PSA regulations outline additional rules related to failure reporting. The relevant PSA regulations contain a total of 44 sections pertaining to the management of "petroleum activities." ABS Consulting has identified the following sections to be pertinent to data collection and failure reporting; Sections 20, 29, 30, 31, 34, 36, and 38.

Regulation Section 20: Registration, review and investigation of hazard and accident situations

PSA Regulation Section 20 provides a thorough written basis for investigations of accidents or environmental hazards. The following passages are relevant as they clearly spell out the basis of the regulatory mandate:

> The responsible party shall ensure that hazard and accident situations that have occurred and that may lead to or have led to acute pollution or other harm, are recorded and examined in order to prevent recurrence.
>
> Situations that occur frequently, or that have great actual or potential consequences, shall be investigated. Criteria shall be set for which situations that must be registered, examined and investigated and requirements shall be set for scope and organization.
>
> The operator shall have a comprehensive overview of hazard and accident situations that have occurred.
>
> The investigation as mentioned in the second subsection, should (e.g., clarify):
>
> a) The actual course of events and the consequences,
> b) Other potential courses of events and consequences
> c) Nonconformities in relation to requirements, methods and procedures,
> d) Human, technical and organizational causes of the hazard and accident situation, as well as in which processes and at what level the causes exist,
> e) Which barriers have failed, the cause of barrier failure and which barriers should have been established, if applicable,
> f) Which barriers functioned, i.e., which barriers contributed to prevent a hazard situation from developing into an accident, or which barriers reduced the consequences of an accident,
> g) Which measures should be implemented to prevent similar hazard and accident situations (Petroleum Safety Authority, 2014).

Finally, Regulation Section 20 includes mandates to combat or prevent pollution: "The investigations … include actions to combat acute pollution, where relevant" (Petroleum Safety Authority, 2014).

Regulation Section 29: Notification and reporting of hazard and accident situations to the supervisory authorities

New Zealand Department of Labor Regulation Section 29 elaborates on the information presented in the PSA's webpage: "The operator shall ensure coordinated and immediate notification via telephone to the Petroleum Safety Authority Norway in the event of hazard and accident situations that have led to, or under slightly altered circumstances could have led to:

a) Death
b) Serious and acute injury
c) Acute life-threatening illness
d) Serious impairment or discontinuance of safety related functions or barriers, so that the integrity of the offshore or onshore facility is threatened
e) Acute pollution" (Petroleum Safety Authority, 2014).

Regulation Section 30: Follow-up and multijurisdictional notification of hazard and accident situations

One unique feature of the Norwegian failure reporting regulations is the regulatory mandate to follow up. This occurs twice in the relevant regulations. In addition, the PSA mandates that in the event of an ongoing pollution problem the Norwegian Coastal Administration should also be informed. This cross-agency notification also appears unique in all of the organizations surveyed in this Task 3 report. The portion of the New Zealand Regulations which govern ongoing follow up read:

> Until situations as mentioned in Section 29, first and third subsections regarding notification of serious or acute hazard and accident situations, are normalized, the operator shall keep the supervisory authorities continuously updated on the development and of the measures it plans to implement.
>
> Before the normalization is concluded following serious or acute hazard and accident situations, the supervisory authorities shall be notified. The supervisory authorities shall be notified if, after the normalization, information comes to light that shows that the hazard and accident situation was more serious than previously reported.
>
> In the event of measures against acute pollution from facilities and offshore vessels, the operator shall ensure that the action plan as mentioned in Section 79 of the Activities Regulations is submitted to the Norwegian Coastal Administration (Petroleum Safety Authority, 2014).

Regulation Section 31: Reporting accidents involving death or injury

Regulation Section 31 specified how accident information should be reported to the Norwegian Labor and Welfare Service and under what circumstances it should be reported. The cross jurisdictional reporting requirement is also mandated in Regulation Section 30, as follows;

In the event of accidents in the enterprise, the employer or the party representing the employer onsite, shall submit written notification to the Petroleum Safety Authority Norway on the specified Norwegian Labor and Welfare Service form for accidents that have resulted in:

a) Death
b) Serious personal injury
c) Disability resulting in absence
d) Medical treatment (Petroleum Safety Authority, 2014).

Regulation Section 34: Information on monitoring, emissions, discharges and risk of pollution.

Regulation Section 34 states that operators are required to submit certain data and records to the Norwegian Environmental Agency to include:

- Monitoring the external environment (references to other sections)
- Information on changes in risk pollution
- Annual report under guidance from Norwegian Environmental Agency
- Results from the risk and emergency preparedness analyses (Petroleum Safety Authority, 2014).

Regulation Section 36 and 38: Reporting damage to load-bearing structures and pipeline systems and reporting for drilling and well activities.

Regulation Sections 36 and 38 deal with database reporting and data terminology. PSA regulations specify that damage to load bearing structures and pipeline is required to be reported to the relevant database and furthermore that reporting should use well and well bore terminology as laid out in regulations:

> The operator shall ensure that damage to and incidents in connection with load-bearing structures and pipeline systems are reported to the Petroleum Safety Authority Norway's Corrosion and Damage (CODAM) database.
>
> The operator shall report drilling and well activities to the Petroleum Safety Authority Norway's and the Norwegian Petroleum Directorate's database. The reporting shall use the well and wellbore terminology, as well as the classification as mentioned in Section 10 of the Regulations relating to resource management in the petroleum activities (Petroleum Safety Authority, 2014).

4.2.2.3 *Role of Industry*

All current operators have been qualified or re-qualified within the last 15 years. (Petroleum Safety Authority, 2015) Therefore, it can be expected that all companies maintain systems that provide proper failure data to PSA, possibly through the recommended L2S software program. As mentioned in Task 2, PSA’s Regulatory Forum allows industry to make substantial contributions to the direction of regulations and guidelines published by PSA. As a consequence, it can also be inferred that reporting requirements set by PSA align reasonably well with the failure reporting already used by these companies.

4.2.2.4 *Effectiveness*

The failure percentage in RNNP is given as the number of failed tests divided by the total number of tests. This represents a possible weakness of RNNP data. Many failures are detected outside tests (e.g., during preventive maintenance, monitoring, inspection or casual observation).

According to RNNP, one of the main achievements has been the adaptation to a more proactive approach to data collection in the industry and the fact that whereas only lagging indicators were available before, they now have both lagging and leading indicators, which enables better planning and execution of implementing risk reducing measures. The overall trend on the NCS, based on RNNP findings, seems to be quite stable for production installations and decreasing for mobile units.

From the PSA's webpage, the following types of incidents require a mandatory telephone notification. This includes incidents which have led, or under slightly different circumstances could have led, to:

- Serious or acute injury;
- Acute life-threatening illness; and
- Serious weakening or failure of safety functions or other barriers so that the facility's integrity is at risk or in the event of acute pollution (Petroleum Safety Authority, 2014).

In addition, reporting contains a time limit. For serious incidents such as the above, notification must be confirmed in writing. If the aforementioned incidents are of a less serious or less acute nature, the operating company must give the PSA specific written notification on the first working day after the incident occurred or was discovered.

4.2.2.5 *Outcomes*

Figure 11 below highlights the overall process of failure reporting under PSA. From this we can see that there are several sources of data that will feed into PSA databases; these databases then provide information into the PSA's failure and risk programs. Ultimately, the data collected from industry is analyzed by the PSA under their programs. The data collection and processing are discussed in the subsequent section but it is important to note the process the data undergoes before the ultimate outcome of PSA analysis is reached.

The overall outcome of the analysis of the data would be entirely dependent on several factors including the regularity of a particular occurrence, the risk of recurrence, potential damages, and other social and market factors. Therefore, while it is not possible to generalize an outcome to a particular equipment failure or the failure process, from Figure 11 below and information from previous sections, there is an analysis process that can lead to policy and procedural changes.

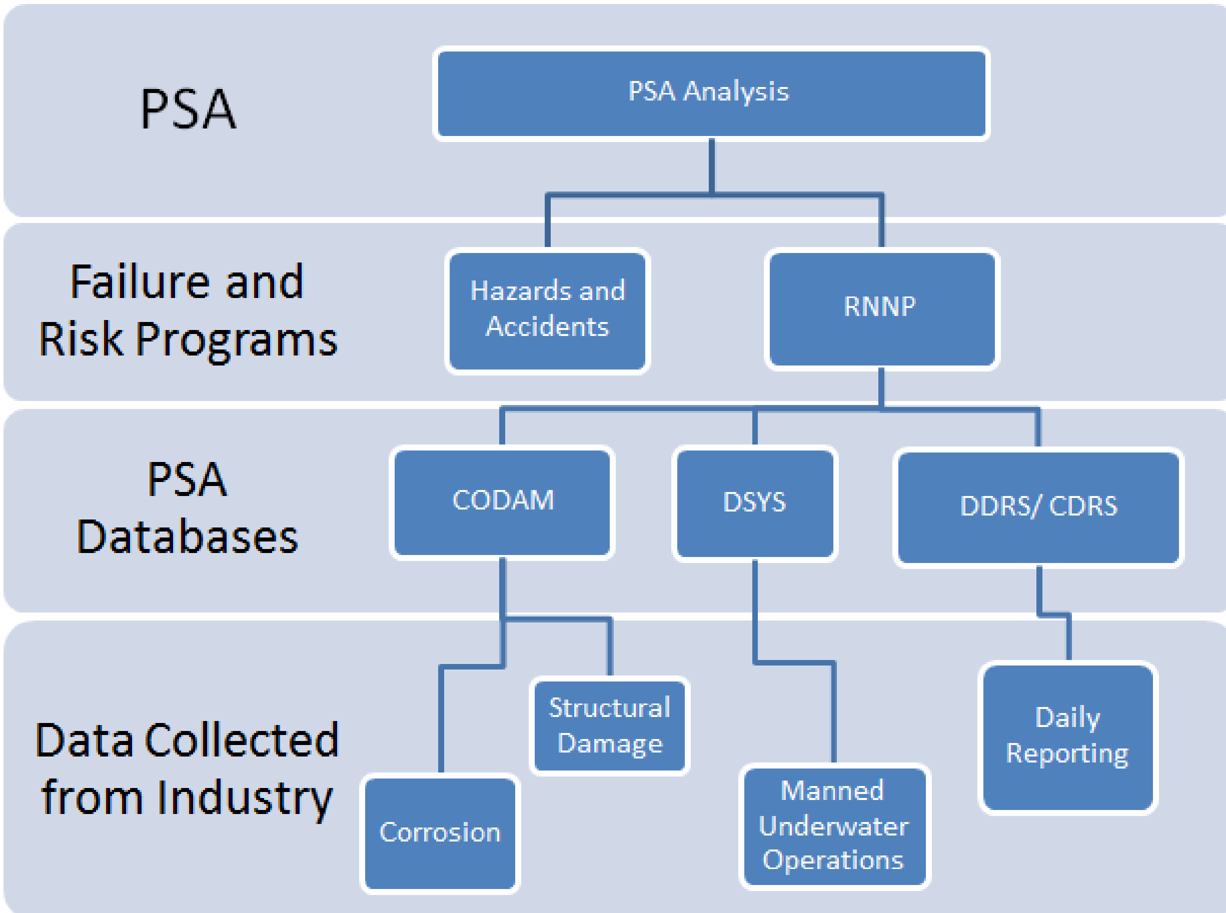

Figure 11: Analysis Process for Policy and Procedural Change

4.2.2.6 *Data*

Within the PSA regulations, Section 19 provides guidelines for the handling of data.

Regulation Section 19: Collection, processing and use of data

While Regulation Section 19 does not use the terminology "failure reporting," the relevant text is similar to language from other sections of this report which mandate that failure reporting data be collected. As noted within the regulation:

> The responsible party shall ensure that data of significance to health, safety and the environment are collected, processed and used for:
>
> a) Monitoring and checking technical, operational and organizational factors,
> b) Preparing measurement parameters, indicators and statistics,
> c) Carrying out and following up with analyses during various phases of the activities,
> d) Building generic databases,
> e) Implementing remedial and preventive measures, including improvement of systems and equipment (Petroleum Safety Authority, 2014).

Overall the data collected will be similar to many other organizations and regulatory bodies in that the data collected will ultimately help inform statistics and any regulatory changes.

PSA's regulations on failure reporting collect Trends in Risk Level in Petroleum Activity; Table 2 below summarizes the type of failure and the mandated data source.

Table 2: Norwegian Safety Authority Failure Data Listing

DFU Description *	Data Sources**
Non-ignited hydrocarbon leaks	Data acquisition
Ignited hydrocarbon leaks	Data acquisition
Well kicks/loss of well control	DDRS/CDRS
Fire/explosion in other areas, flammable liquids	Data acquisition
Vessel on collision course	Data acquisition
Drifting object	Data acquisition
Collision with field-related vessel/installation/shuttle tanker	CODAM
Structural damage to platform/stability/anchoring/ positioning failure	CODAM and Industry
Leaking from subsea production systems/pipelines/risers/flow lines/loading buoys/ loading hoses	CODAM
Damage to subsea production equipment/pipeline systems/diving equipment caused by fishing gear	CODAM
Evacuation (precautionary/emergency evacuation)	Data acquisition
Helicopter crash/emergency landing on/near installation	Data acquisition
Man overboard	Data acquisition
Injury to personnel	Personal Injury Protection
Occupational illness	Data acquisition
Total power failure	Data acquisition
Diving accident	DSYS
Hydrogen sulfide (H_2S) emission	Data acquisition
Falling object	Data acquisition

* DFU-defined situations of hazard and accident

** Data acquired with the cooperation of operators (Petroleum Safety Authority, 2010)

Company anonymity is maintained in PSA's published reports, which are intended to identify trends in healthy, safety, and environmental metrics as applied to the O&G industry. Data can then be used by the industry to consider areas of improvement in fields PSA reports identified. Given the heavy involvement of industry with PSA regulatory formation, these reports provide an objective basis on which discussions between the two parties are centered.

4.2.2.7 *Liabilities*

Regulations pertaining to health, safety, and the environment in petroleum activities are enforced by PSA, the Norwegian Environment Agency, and the Norwegian Labor Inspection Authority, within their respective authorities. All regulations and guidelines, according to PSA, "are not legally binding." Instead, "the regulations and the guidelines should be viewed jointly in order to obtain the best possible understanding of what the government wishes to achieve by their means" (Petroleum Safety Authority, 2015).

4.2.2.8 *Application to BSEE*

The findings from PSA have some applicability to BSEE operations. First, the regulations mandate reporting to PSA and other Norwegian state agencies like the Norwegian Labor and Welfare Service. This dual mandate is unique in that one set of regulations oblige Norwegian operators to report any failures to two oversight agencies. While speculative, this may reduce any potential gaps in oversight between regulatory agencies.

Second, PSA mandates ongoing reporting. In the event of an ongoing incident (a chronic spill for example), operators need to keep PSA informed until the incident is resolved. This follow-up mandate does not appear to be a prominent part of Domestic Federal Oversight and could be considered in any re-write of BSEE regulatory rules if policymakers conclude that additional oversight is needed.

Third, the risk indicators used in RNNP seem reasonable and useful, whereas the details of the collection seem to be too limited to obtain more than just overall trends. This is the opposite problem of the ISO 14224, where failure events and associated equipment is recorded in detail, whereas consequences with regard to HSE are not emphasized. Hence, these two Failure Reporting schemas are complimentary and a combination of the two could provide all necessary information to obtain a good overview of both risk level, equipment reliability and their interdependencies. It also validates the point which is made in ISO/TR 12489, which recommends an approach where safety and reliability/production is evaluated in combination.

4.2.3 United Kingdom, Health and Safety Executive

The UK's HSE is the health and safety regulatory body for Great Britain. HSE is responsible for developing, managing and enforcing health and safety regulations. The Health and Safety at Work Act of 1974 is the legislative framework HSE follows to provide guidance, training, education and enforcement as it applies to occupational health and safety in Great Britain.

This section of the report discusses programs within the UK's HSE that contain failure reporting. The primary program aspects of failure reporting can be found in the Reporting of Injuries, Diseases, and Dangerous Occurrences (RIDDOR).

HSE's RIDDOR failure reporting system was created in 1995 and is still in current use as HSE's sole incident reporting system for specified injuries to workers. It functions to put "duties on employers, the self-employed and people in control of work premises (the Responsible Person) to report certain serious workplace accidents, occupational diseases and specified dangerous occurrences (near misses)."

The types of reportable injuries under RIDDOR include:

- Death;
- Fractures, other than to fingers, thumbs and toes;
- Amputations;

- Any injury likely to lead to permanent loss of sight or reduction in sight;
- Any crush injury to the head or torso causing damage to the brain or internal organs;
- Serious burns (including scalding) which:
  - Covers more than 10% of the body;
  - Causes significant damage to the eyes, respiratory system or other vital organs;
- Any scalping requiring hospital treatment;
- Any loss of consciousness caused by head injury or asphyxia;
- Any other injury arising from working in an enclosed space which:
  - Leads to hypothermia or heat-induced illness;
  - Requires resuscitation or admittance to hospital for more than 24 hours (UK Health and Safety Executive, 2014).

4.2.3.1 *Information, Policies, and Procedures*

When developing the Ageing and Life Extension Inspection Programme, also known as Key Program 4 (KP4), HSE's LCM program (discussed in the previous Task 2 Report: LCM Systems), HSE states that "the key databases interrogated were RIDDOR, including the chemical and process industry voluntary incident reporting schemes, the Major Accident Reporting System (MARS) (EU Seveso II major hazard Incidents) and the Major Hazard Incident Data Service (MHIDAS) database (worldwide major hazard accidents)" (UK Health and Safety Executive, 2014).

Addressing first MARS and MHIDAS databases, it should be noted that both are no longer managed and updated. It appears that RIDDOR is the only database HSE currently uses. MARS was managed by the Major Accident Hazards Bureau from 1980 to 2002. The Major Accident Hazard Bureau "provides research-based scientific support to the European Community on the formulation, implementation and monitoring of European Union (EU) policies for the control of major accident hazards." Thus while the Major Accident Hazard Bureau is not a regulatory agency itself, it functions as an objective foundation upon which HSE, and most likely other regulatory bodies in the EU, build their programs (European Environment Agency, n.d.).

From the information gathered, it appears as if the HSE was the primary manager of the MHIDAS database. It is unknown how long HSE managed it, or when they ceased to manage it, or whom, if anyone, took over that responsibility. Overall, MHIDAS performs similar functions to RIDDOR, except specifically that it, "contains information on incidents involving hazardous materials that result in or have the potential to produce off-site impact," whereas RIDDOR deals only with onsite work-related incidents. MHIDAS collected data on incidents such as "date and place; hazards … incident type; origin; general and specific causes; quantity of material released or consumed; number of people killed, injured, or evacuated … and a description of the event." While MHIDAS is probably no longer in use by HSE, similar databases are hosted by HSE, Major Accident Hazards Bureau, National Transportation Safety Board and Occupational Safety and Health Administration (OSHA) (Info Mimet, n.d.).

RIDDOR is a software program developed by Intelex. No pricing information could be obtained at this time. In addition to RIDDOR, Intelex also provides software packages that deal with ISO, Occupational

Safety and Health Administration Services, and OSHA compliance. RIDDOR specifically is associated with the O&G industry, but Intelex also markets its products to the automotive, aviation and aerospace, construction, energy (electricity), healthcare, and mining. The historical performance of the RIDDOR software package is unknown at this time (International Business Machines, n.d.).

4.2.3.2 *Elements, Best Practices, Lessons Learned*

RIDDOR covers the reporting of work-related deaths and injuries. For the reporting requirements, there are specific definitions for the incident once an accident has caused an injury, to ensure the accident is work related and the injury is a type that is reportable (UK Health and Safety Executive, n.d.).

Specifically for the requirements under RIDDOR, "an accident is a separate, identifiable, unintended incident, which causes physical injury. This specifically includes acts of non-consensual violence to people at work." (UK Health and Safety Executive, n.d.). This means an accident under RIDDOR needs to be an independent event, isolated from a possibly larger set of events. RIDDOR also separates the injuries from an accident and specifies that an injury, in and of itself, is not an accident but rather the event that leads to an injury is the accident. Finally, RIDDOR specifies that constant exposure to a hazard that leads to an injury (e.g., repeated lifting of heavy objects) is not considered an accident under RIDDOR (UK Health and Safety Executive, n.d.).

RIDDOR then specifies what constitutes a "work-related" injury. The definition of a work-related injury is one where if the manner in which work was carried out, if any machinery plant, substances, or equipment used for the work, or if the condition of the site or premises played a significant role in an accident occurring (UK Health and Safety Executive, n.d.). Therefore, just because an accident occurs on work premises, does not mean it is work-related. Specifically, the accident must be based on the work activity (UK Health and Safety Executive, n.d.). The definition allows for work-related accidents to not necessarily have to occur just on work premises but also includes offsite work.

The final primary definition addressed by RIDDOR is what constitutes a "reportable" injury. Based on the previous definitions of a work-related accident, a reportable injury is considered where one of the following occurs: a death of a person, a specific injury to a worker, an injury to a worker that results in them being unable to work for more than seven days, or any injuries to non-workers in which they need to be taken directly to a hospital for treatment (UK Health and Safety Executive, n.d.). Each of these aspects of a reportable injury corresponds to a specific regulation within RIDDOR that further provides guidelines for how these definitions are applied or addressed. There is no direct relationship readily available between the statistics and any OEMs.

4.2.3.3 *Role of Industry*

RIDDOR came into effect under HSE in 1995.While it is not known which of these companies specifically purchased RIDDOR or some other Intelex package, all of the duty holder companies mentioned in the previous Task 2 report most likely also use RIDDOR as they drill within HSE's jurisdiction. Industry members look to the use of the standards set forth under RIDDOR because of the comprehensive manner in which the definitions and guidelines are presented as well as the relationship between the standards under RIDDOR and the regulatory standards an industry member would already be required to follow when reporting incidents to HSE. Additionally, the resources under RIDDOR assist industry members to track and better understand work related injuries. While it is unknown how long specific companies have used RIDDOR, it is safe to assume that industry members could benefit greatly from employing the guidelines set by RIDDOR.

4.2.3.4 *Effectiveness*

While the HSE produces an annual "Health and Safety Statistics Report" for Great Britain, it does not provide recommendations or express opinions about the overall effectiveness of its programs and systems. After enacting several major changes to the RIDDOR system in October of 2013 dealing with the classification of certain accidents, the HSE seems to project an overall high level of confidence in its failure reporting system (UK Health and Safety Executive, 2014).

In 2014, with the publication of a quality report on RIDDOR data, HSE assessed the data it obtained on:

- Relevance;
- Accuracy and Reliability;
- Timeliness and Punctuality;
- Accessibility and Clarity;
- Coherence and Comparability;
- Trade-offs between Output Quality Components;
- Assessment of User Needs and Perceptions;
- Performance, Cost, and Respondent Burden; and
- Confidentiality, Transparency, and Security.

While the reporting of fatal accidents is nearly perfect due to the investigations and analysis that go into them, HSE believes that non-fatal accidents are underreported and acknowledges this on numerous occasions in the quality report (UK Health and Safety Executive, 2014).

Anonymity is preserved when HSE publishes its annual statistical report. As this report does not make recommendations, it serves the purpose of a comparative year-by-year assessment as to how well its health and safety programs are working, such as KP4. Though all companies that participate have access to the annual report, HSE may provide additional guidance and recommendations through other outlets to minimize incident occurrences. Outside of KP4, this guidance has not been thoroughly researched.

In terms of the data reported through RIDDOR, HSE has a Confidentiality Policy that states all data is:

> …handled, stored and accessed in a manner which complies with Government and Departmental standards regarding security and confidentiality, and fully meets the requirements of the Data Protection Act. Access to this data is controlled by a system of passwords and strict business need access control. To avoid the disclosure of personal information through statistical outputs, disclosure control is implemented where deemed necessary, especially where small counts are involved. (UK Health and Safety Executive, 2014).

RIDDOR only accounts for accidents and incidents in which people are harmed or nearly harmed. While it does require information about equipment as it pertains to the incident, RIDDOR primarily seeks out information relating to human health and safety. In regards to the KP4 program, the same interests appear to hold for HSE as it states "the [KP4] program investigated the impact of ALE on the risk of major accidents involving the death or serious personal injury to people on an offshore installation" (UK Health and Safety Executive, 2014).

The RIDDOR forms provided through the HSE website fall into seven distinct categories. The data requirements for each reporting form are listed below:

Injury

- Notifier name, job title, organization name, contact information
- Incident date, time, department, type of work, local authority
- Kind of accident, work process involved, main factor, description of event
- Injured person's general information (age, sex, occupation, contact)
- Description of injuries, severity, part of body affected

Dangerous Occurrence

- Notifier name, job title, organization name, contact information
- Incident date, time, department, type of work, local authority
- Type of occurrence, description of occurrence

Injury Offshore

- Notifier name, job title, organization name, contact information
- Name of the offshore installation, coordinates, details of the vessel
- Incident date, time, department, type of work, local authority
- Kind of accident, work process involved, main factor, description of event
- Injured person's general information
- Description of injuries, severity, part of body affected

Dangerous Occurrence Offshore

- Notifier name, job title, organization name, contact information
- Name of the offshore installation, coordinates, details of the vessel
- Incident date, time, department, type of work, local authority
- Type of occurrence, description of occurrence

Case of Disease

- Notifier name, job title, organization name, contact information
- Type of work, local authority
- Affect person's general information (age, sex, occupation, contact)
- Date of diagnosis, disease diagnosed, details of work activity that led to disease

Flammable Gas Incident

- Notifier name, job title, organization name, contact information

- Incident date, main cause, address, local authority
- If premises were rented, landlord contact information
- Number of deaths, major injuries, description of incident

Dangerous Gas Fitting

- Notifier name, job title, organization name, contact information
- Date found, how it was found, local authority
- If found in a building, building type, room, resident name
- If premises were rented, landlord contact information
- Main fault, appliance involved, gas involved, design of appliance, was the appliance second-hand, summary of fitting (UK Health and Safety Executive, 2014)

4.2.3.5 *Outcomes*

RIDDOR report forms can be obtained and submitted directly through HSE's website, or RIDDOR software can be purchased through Intelex. Once a duty holder reports an incident to HSE, a copy of his or her submitted form is sent back for record-keeping purposes. No additional information on the path each report takes is known at this time. Figure 12 is a flowchart of the RIDDOR reporting process.

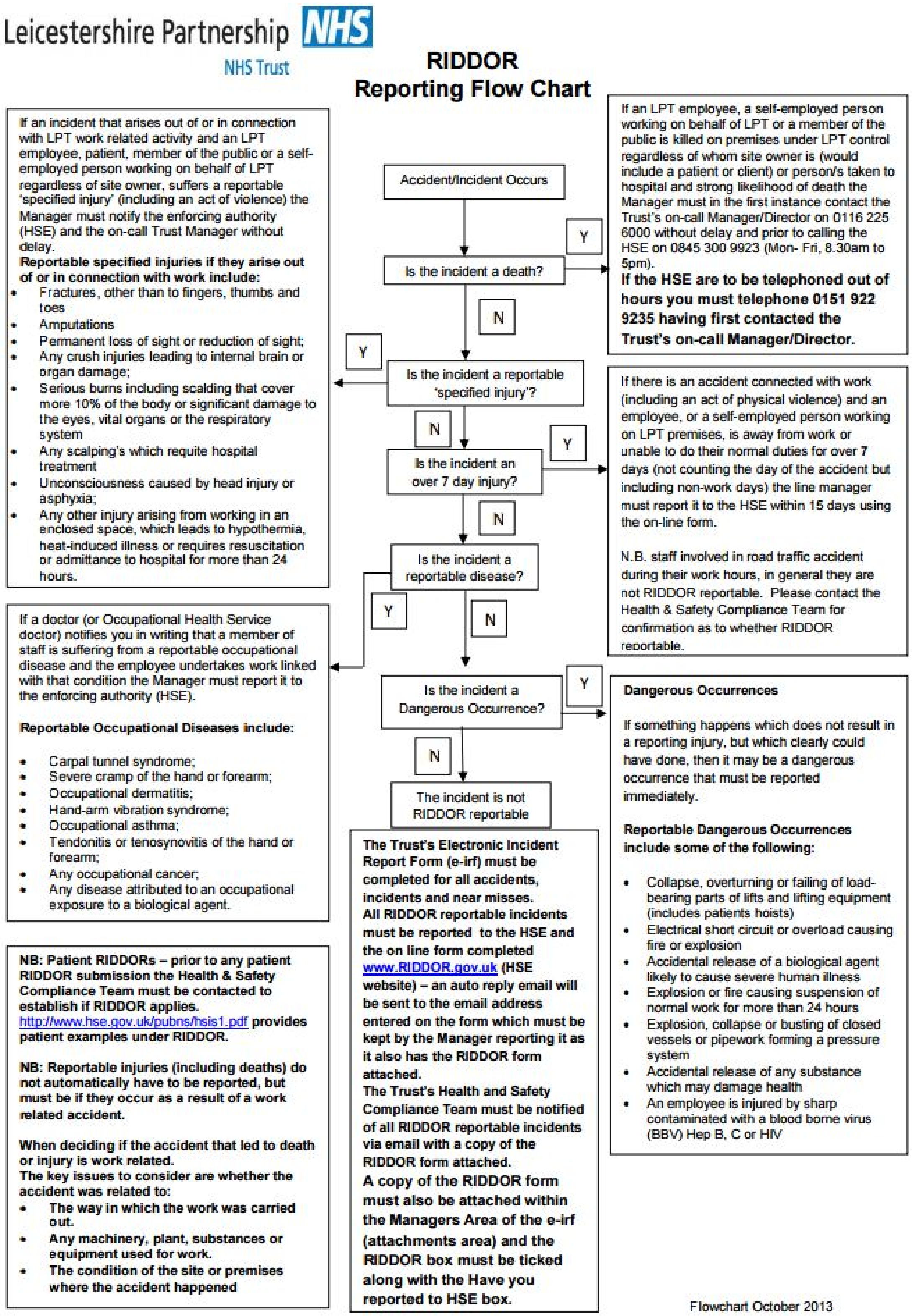

Figure 12: RIDDOR Reporting Flow Chart
(Leicestershire Partnership NHS Trust, 2013)

4.2.3.6 *Data*

While there are no direct examples of service providers utilizing Health and Safety Statistics, the UK's HSE maintains records of enforcement actions taken due to the number of injuries and incidents that are reported.

The best data available on the HSE's overall progress towards a healthier and safer workforce can be found in their annual statistics report.[9] Some of the statistics found in their annual report range include fatal diseases, fatal accidents, self-reported injuries, and other categories. Generally speaking, the annual RIDDOR report provides the data over several years so that trends for various incidents can be observed.

While this report utilizes data from multiple sources, including RIDDOR, effectiveness of a particular program like KP4 cannot be determined.

4.2.3.7 *Liabilities*

Information that is supplied to HSE under RIDDOR is protected from the industry members' insurance company. However, HSE does advise the timely reporting of injuries and illness to insurance companies as it may possibly save the Duty Holder time and money (UK Health and Safety Executive, n.d.).

RIDDOR, while compulsory for Duty Holders to submit reports from, does suffer from underreporting issues in non-fatal accidents (see Section 4.2.3.4). Non-reported accidents under RIDDOR can result in serious repercussions. An example can be found on the HSE Regulating and Enforcing site.[10]

It should be noted that enforcement can result in significant fines, sanctions, or even a change in the Duty Holders' internal policies and procedures. Sanctions will vary from case to case but can include loss of various operating permits.

4.2.3.8 *Application to BSEE*

RIDDOR, given its long track record of 20 years in use, nevertheless suffers from a lack of data reporting on non-fatal incidents. While the HSE acknowledges this, no discernable actions have been taken to correct it other than some reclassification of types of injuries made in the last few years. A crucial obstacle to a solution is that of enforcing non-fatal reporting on such a large scale of Duty Holders. In the development or revisions of a failure reporting system, BSEE must necessarily take this issue into account, as well.

4.3 Industry

The information in this section describes the data collected for the following organizations: ISO, API and IADC. In addition, we review commercially available failure reporting software packages to include: ReliaSoft's XFRACAS and International Business Machines' (IBM) Maximo.

[9] This can be accessed at the following website: http://www.hse.gov.uk/statistics/overall/hssh1314.pdf

[10] Examples are provided at the following website: http://www.hse.gov.uk/enforce/examples/riddor.htm .

4.3.1 American Petroleum Institute

The API is the trade association representing the Petrochemical Industry in the U.S. The API has more than 600 corporate members across all segments of the petrochemical industry. The API has a number of organizational goals/activities including advocacy, research and statistics, standards setting, certification, licensing and safety, as well as events and training functions.

In order to accurately review the state of failure reporting systems, ABS Consulting conducted a review of existing API standards. As with Section 4.3.3 , there is commonality between both sets of industry standards. Both are industry standards organizations that set safety standards for their industries, but also, the ISO standards have similar, or the same, content as the API standards. Due to this, API has recently increased limitations on the distribution and attribution of their standards.

4.3.1.1 *Information, Policies, and Procedures*

For the purposes of this report, ABS Consulting selected the following API standards that have failure reporting components:

API 16AR – API Monogramed Parts

This standard is also discussed in our Task 2 Report: LCM Systems. For more information on this standard, please see the Task 2 Report.

In general, API written documents indicate that the responsibility for failure reporting should lie with the original manufacturer of oil and natural gas equipment (American Petroleum Institute, 2014). For example, API standards for specially monogramed API drill through parts indicate that any part which received an API monogram or logo needs to have an associated failure reporting system. It is the responsibility of the original manufacturer to manage and maintain this failure reporting system.

API Specification 16AR also goes on to summarize the outlines of the failure reporting system. While not specific, API 16AR outlines general procedures for users, manufacturers, and repairers of API monogramed products. Specifically, API recommends that in the event of part malfunction or failure, users should send a detailed written report to the manufacturer which outlines the failure and the relevant operating history and operating conditions. Second, the API recommendations call for manufacturers to formally communicate failure incidents to their internal manufacturing teams and produce written records of changes to each model of equipment. Manufacturers should also send notification to all users of the relevant equipment once a part defect has been identified.

API specifications also mandate a role for repairing organizations. Any time an API monogrammed part is repaired, a report should be sent from the repairing organization to the manufacturer which lists the conditions surrounding the failure or the malfunction, as well as product change recommendation's which should be made to bring the part into compliance with manufacturer changes (American Petroleum Institute, 2014). The process flow for this standard is shown in Figure 13.

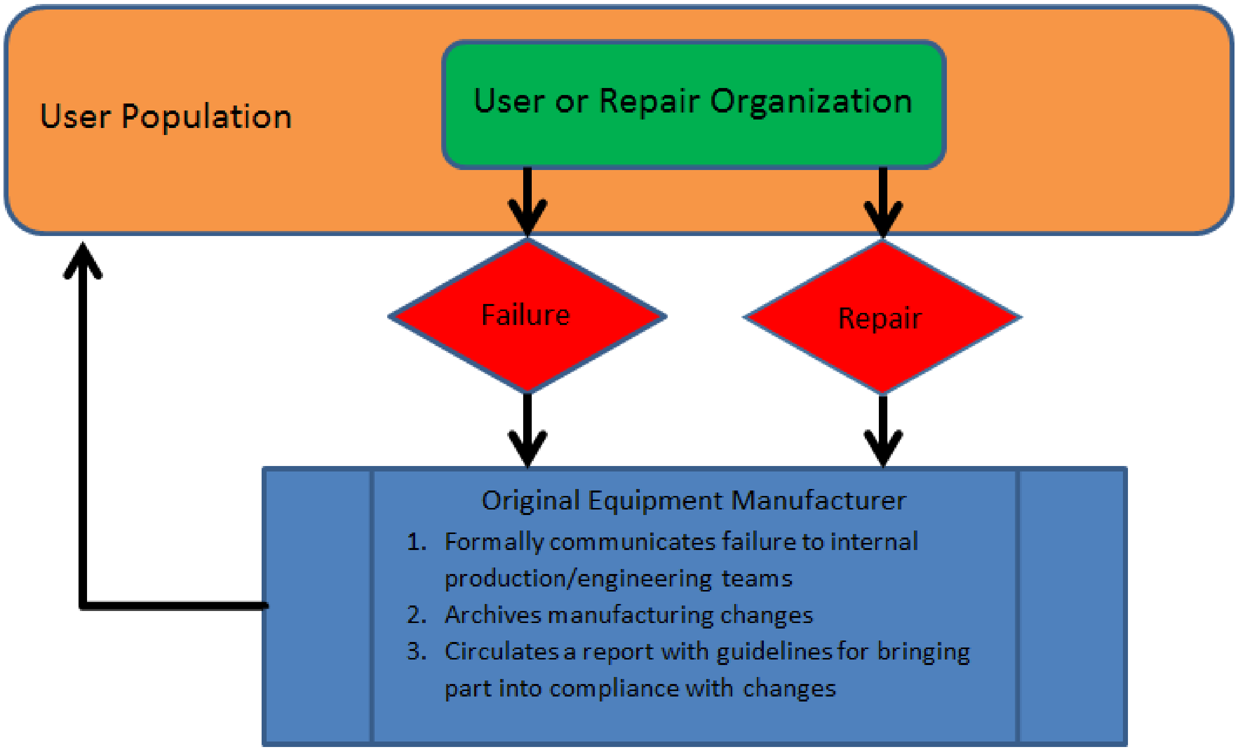

Figure 13: API Failure Reporting Process 16AR – API Monogrammed Parts Flowchart

API 14B – Subsurface Safety Valve Systems

API standards also govern failure reporting for Subsurface Safety Valve (SSSV) Systems. In ANSI/API RECOMMENDED PRACTICE 14B "Design, Installation, Repair and Operation of [SSSV] Systems." These standards dictate a set of very specific actions to take in the event of an equipment failure. These are:

1. Equipment operators shall submit a report to the equipment manufacturer within 30 days of discovery and identification of the failure.
2. The operation shall perform a failure analysis, either in partnership with the manufacturer or independently. If independently conducted, the operator will send the results of the failure analysis to the manufacturer within 45 days of completion.
3. The manufacturer shall respond to the results of the analysis in accordance with the failure reporting requirements outlined in ISO 10432.[11]

API standards are also quite detailed as to the type of information included in failure reporting for SSSVs. This information includes, at a minimum:

A. Operator Data

[11] See: ISO 10432:2004, Petroleum and natural gas industries -- Downhole equipment -- Subsurface safety valve equipment.

1. *Operator data*: Operator, name, field/area, lease name and well number, operator signature and date.
2. *SSSV equipment identification*: model, manufacturer, SSSV lock and landing nipple number, irretrievability of SSSV tubing, wiring and equipment, serial number, working pressure, service class and redress history records.
3. *Well data*: Well test rate, environmental conditions, percent sand, H_2S, CO_2, pressures and temperatures, surface, bottom hole, SSSV equipment settling depth and installation rate, time equipment in service and presence of unusual operating conditions.
4. *Description of Failure*: Nature of failure, observed conditions which could have caused failure.

B. Manufacturer Data

1. *Failed Equipment Condition*: condition as received, failed components, damaged components.
2. *Test results:* If test was furnished by operator or conducted by manufacturer, failure modes, leakage rate, control fluid, and operational data (opening and closing pressures).
3. *Cause of failure*: probable and secondary causes.
4. *Repair and maintenance*: parts replaced and other maintenance and repair.
5. *Corrective action to prevent recurrence*: Operator procedures, design/material change, proper equipment application.
6. *Additional Information:* Facility location where failed valve was originally manufactured, date of manufacture.
7. *Manufacturers Information*: Signature and date.

Figure 14 below shows the failure reporting process for this standard.

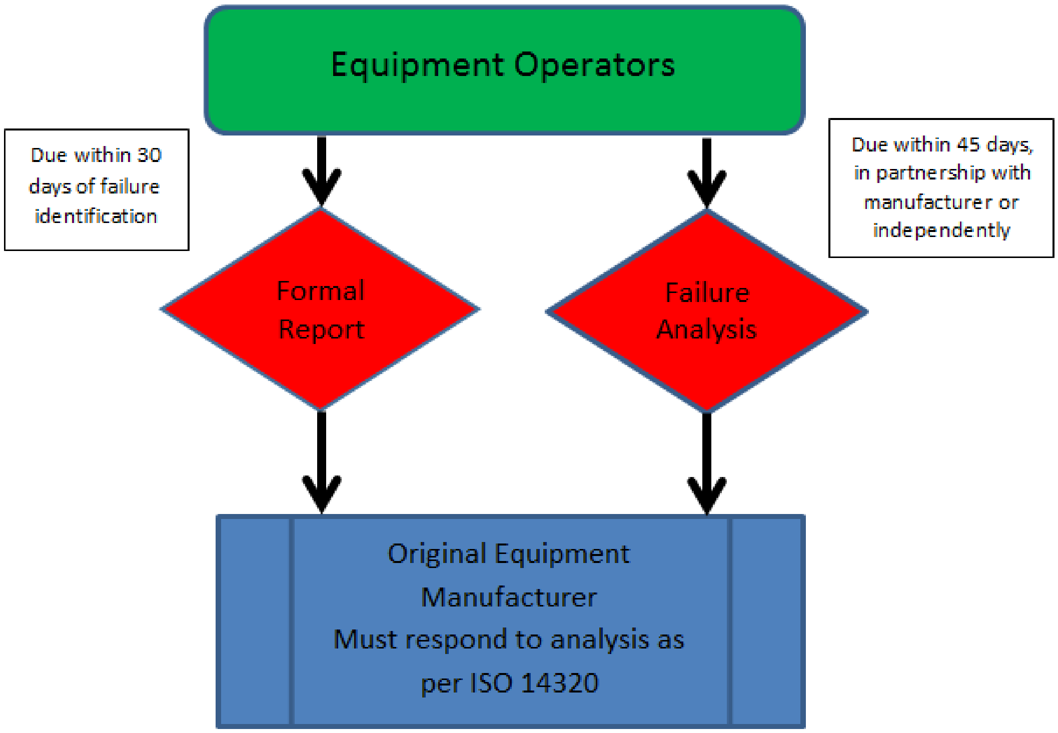

Figure 14: API Failure Reporting Process 14B – Subsurface Safety Valve Systems Flowchart

API 6A – Specification for Wellhead and Christmas Tree Equipment

In general terms, API 6A calls for a failure reporting system using the following steps (see Figure 15): first, after receiving a failure report from the operator, the manufacturer of the Surface Safety Valve (SSV)/Underwater Safety Valve (USV) equipment shall respond within six weeks of receipt, describing progress in the failure analysis. Second, the manufacturer shall also update the operator in writing with the final results of the analysis and the corrective action. Third, if the failure analysis causes the equipment manufacturer to change the design, assembly, or operating procedures of a given piece of equipment, the manufacturer shall, within 30 days of such changes, report them in writing to all purchasers and/or known operators of equipment having potential problems (American Petroleum Institute, 2013).

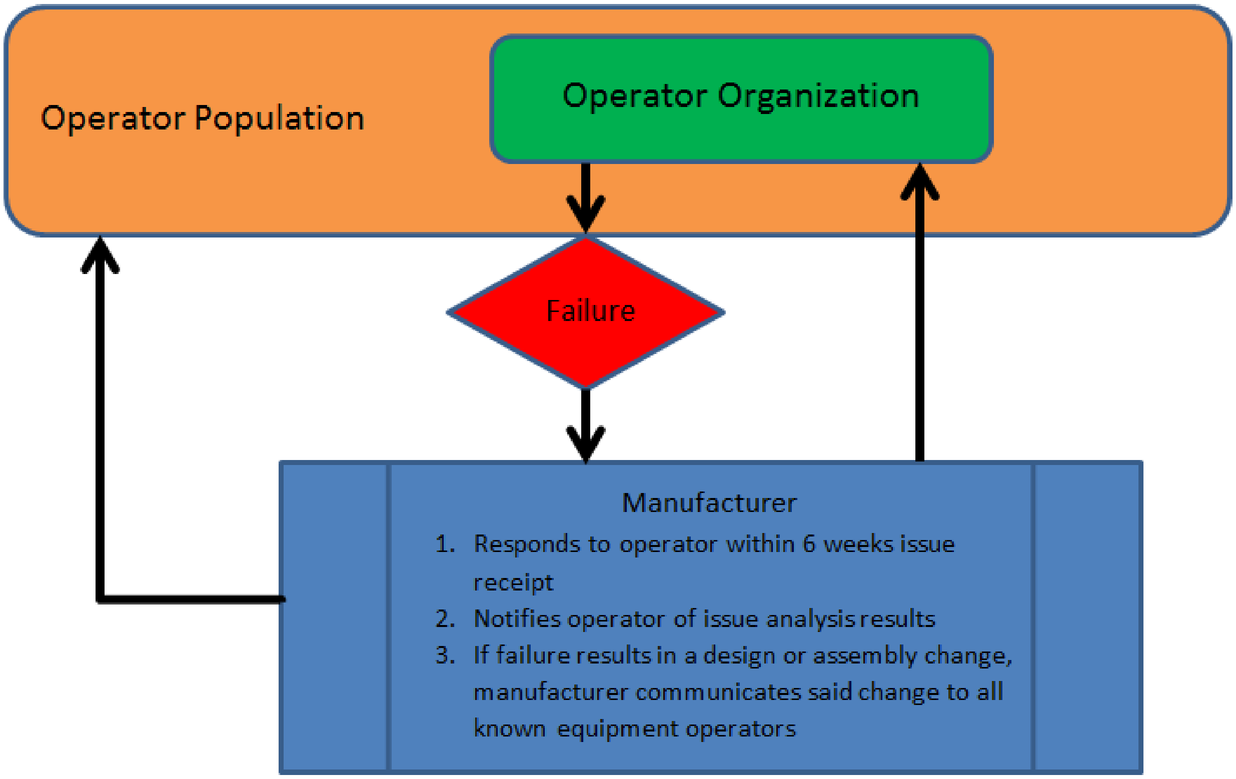

Figure 15: ANSI/API Failure Reporting Process 6A – Wellhead & Christmas Tree Equipment Flowchart

API 6AV2 – Safety Valves

API recommended practice 6AV2 details the procedures used for reporting failures in SSV/USV and related equipment. In a nutshell, when an event occurs, the operator of the equipment shall provide a written report to the manufacturer and/or associated good provider detailing the failure event. If a subcontractor is involved in operating the equipment the subcontractors' role should be noted in the associated report. Recommended practice 6AV2 specifies in detail which kind of information should be provided. The details are shown in three parts:

A. Failure Checklist

1. Identification information: operator name, date of occurrence, field/area, lease name/platform/well number, equipment identification
2. SSV/USV actuator data: vendor, model, size, part number, serial number, control operating pressure, SSV/USV actuator control fluid, actual installed water depth
3. SSV/USV valve data: vendor, model, size/pressure rating, temperature rating, part number, serial number
4. SSV lock-open device: vendor, model and part number
5. Remotely Operated Underwater Vehicle (ROV) lock-open device: vendor, model and part number

6. Well data: flow, percent flow rate Gas, Oil, H_2S, CO_2, percent sand, parts per million (PPM) chlorine, parts per billion (PPB) oxygen, PPM mercury, PPM elemental sulfur, flowing and shut in
7. Description of failure: failure mode, valve pressure containment (yes/no), valve pressure control (yes/no), estimated rate of leak, valve/actuator operation (failure to open/close, yes/no), actuator pressure containment (piston, stem seal yes/no), lock-open device, suspected cause of failure (whether product defect, excessive wear, erosion, maintenance, corrosion)
8. Manufacturer data: Identification of failed components (e.g., Gate or seat), component name and description), equipment, vendor, model size and suspected cause of failure, determined root cause

B. Field Repair Record Sheet (the Field Repair Data Sheet contains much of the same information fields as the failure checklist information)

1. Identification information: operator name, date of occurrence, field/area, lease name/platform/well number, equipment identification
2. SSV/USV actuator data: vendor, model, size, part number, serial number, control operating pressure, SSV/USV actuator control fluid, actual installed water depth
3. SSV/USV valve data: vendor, model, size/pressure rating, temperature rating, part number, serial number
4. SSV lock-open device: vendor, model and part number
5. ROV lock-open device: vendor, model and part number
6. Replaced components list: part number and serial number of replaced parts, number of parts replaced, description, part number and serial number of new parts, manufacturer of new parts
7. Name of persons performing repairs: Name, title, company, signature and date

C. Function Test Data Sheet (the Functional Test Datasheet has similar information to the failure checklist and the field repair record sheet)

1. Identification information: operator name, date of occurrence, field/area, lease name/platform/well number, equipment identification
2. SSV/USV actuator data: vendor, model, size, part number, serial number, control operating pressure, SSV/USV actuator control fluid, actual installed water depth
3. Test information: functional test date
4. SSV/USV actuator seal test: normal operating pressure, actual test pressure, test media
5. Drift test: drift test (pass/fail), measured diameter of drift mandrel/bar/tool, visual inspection(pass/fail)
6. SSV/USV operations test: number of cycles completed with SSV/USV valve body at atmospheric pressure, number of cycles completed with SSV/USV valve body exposed to shut-in tubing pressure (SITP)

7. SSV/USV valve leakage test: well SITP, test pressure, test start time, test end time, pressure containing components met acceptance criteria (yes/no), pressure control components met acceptance criteria (yes/no), leakage rate, method, measured properly, met acceptance criteria (yes/no)
8. SSV/USV valve data: vendor, model, size and pressure rating, temperature rating, part number, serial number
9. SSV lock-open device: vendor, model and part number
10. ROV lock-open device: Vendor, model and part number
11. Name of persons performing repairs: Name, title, company, signature and date

All three of these blocks of information are included in neatly formatted field repair record sheets and displayed in the relevant appendices of API Standard 6AV2. The failure reporting process for this standard is shown in Figure 16 below:

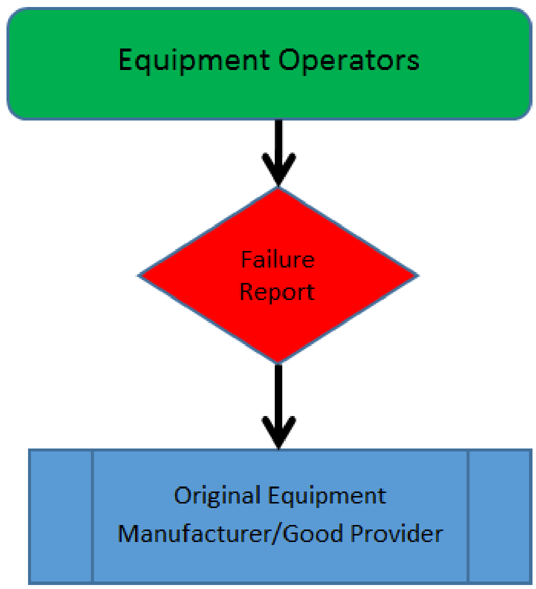

Figure 16: API Failure Reporting Process 6AV2 – Safety Valve Systems Flowchart

API Standard 53

API STD 53 addressed the management of BOP systems for petrochemical wells. Appendix B of this standard contains generalized guidelines for failure reporting. Briefly summarized, this guideline states that in the event of a failure, equipment users should provide a report to the manufacturer, who if necessary will provide internal and external recommendations.

The nature of the reporting is also mandated in API STD 53. For example, the equipment owners report should provide as much detail as possible regarding operating conditions which existed at the time of the malfunction or failure, a description of the possible malfunction/failure, and details regarding previous repairs, modifications or other relevant operating details.

After receiving the report, API STD 53 mandates a manufacturer response. This involves a number of steps. First, any problems experienced during manufacture, testing or use should be formally communicated to the individual or group within the manufacturing organization responsible for design or specification documents. Manufactures need to have written procedures for making these types of communications, as well as records for material changes or corrective action taken in response to the failure.

Finally, manufacturers are to provide external recommendations. API STD 53 mandates that all significant problems need to be reported to equipment owners within three weeks of a failure. Also, any design changes resulting from a malfunction or failure must be conveyed within 14 days after the design change (American Petroleum Institute, 2012). The process for this standard is shown in Figure 17 below.

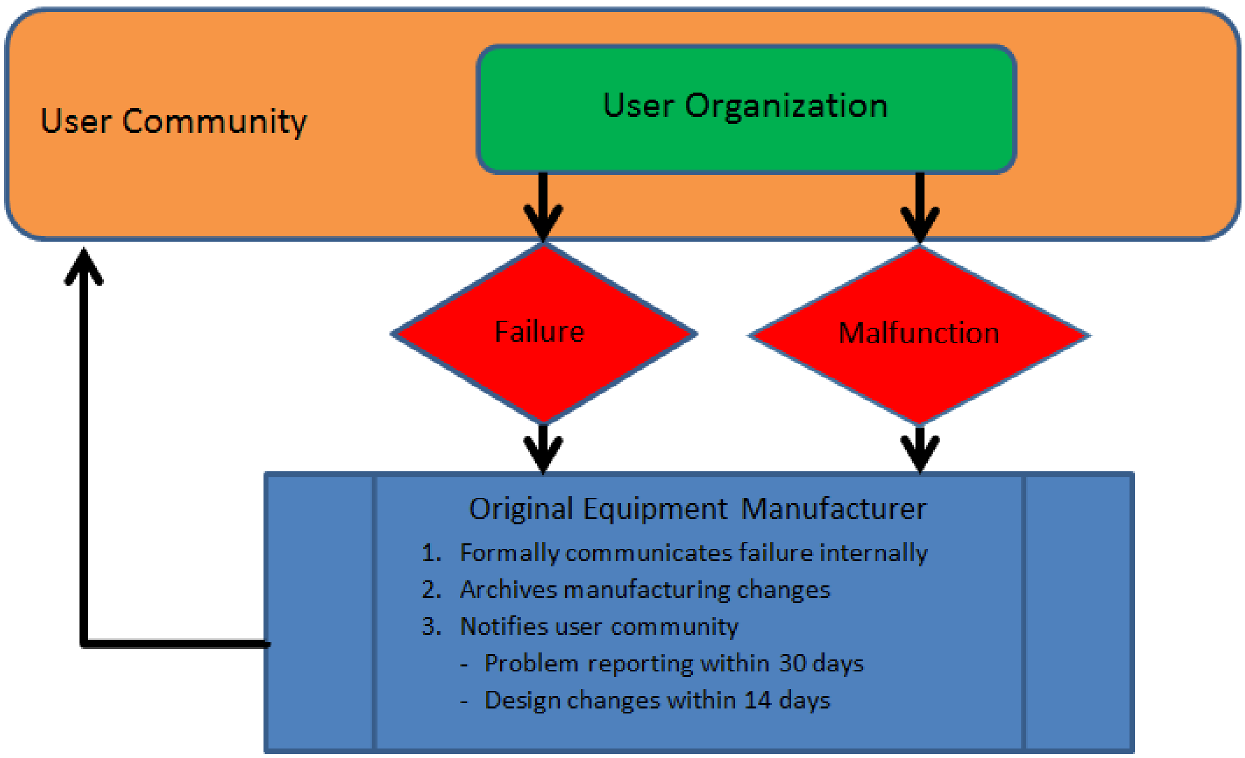

Figure 17: API Failure Reporting Process API STD 53 – Well BOP Equipment Flowchart

4.3.1.2 *Elements, Best Practices, Lessons Learned*

API standards are industry-driven, voluntary in nature, and are developed using a consensus-based system of voting. These sets of guidelines tend to be general in nature and do not prescribe specific types of software, data types, or failure reporting data transmission formats. However, failure reporting systems are recommended as part of API's issued guidelines. As a general rule, API standards are kept up to date. For example, most of the API standards included in this review are dated from the early 2010s; with API 16AR recently revised in 2013 and API 14B revised in 2012 (American Petroleum Institute, 2014).

Due to API's relationship with the U.S. O&G industry, much of their standards are developed by and for the industry. This provides API the access and availability of the technical experts from across the industry providing development of standards. This allows API to develop standards that should be technologically sound and acceptable to the industry. The main concern from this relationship with the industry and from the consensus-based approach is that while these standards may be more rigorous than current regulatory requirements, the standards may still be lacking or achieve the appropriate level of safety that might be desirable.

Since each standard is often developed separately, there are commonalities among each standard, but they are not consistent. Many standards have a feedback mechanism to either the OEM or to the industry, but this is not the case in each standard.

Since API standards are industry-developed and are being used by industry (particularly by the large O&G companies), incorporation of these standards by BSEE would be an achievable first step by using these standards as the foundational structure in the development of a failure reporting requirement. API standards are meant for the U.S. O&G industry, thus the international industry may adopt an international standard, like ISO standards (see Section 4.3.3). Many of the ISO standards tend to directly reflect the API standards on the same or similar topics, with conversions to the metric system. Due to the similarity between the standards, incorporating both the API standard and setting the ISO standard as an equivalency is achievable. A concern about ISO equivalency is if ISO standards are following the development of API standards, then there may be a gap in the refresh rate for ISO standards.

4.3.1.3 *Effectiveness*

In order to determine how the API determines the effectiveness of their programs, ABS Consulting spoke with our in-house SMEs. In general, the SMEs reported that API does not conduct formal scientific studies of the effectiveness of their programs and instead rely on the committee system to updated and revise as needed.

Industry feedback on API standards does come through the API committee process. The API committees consist of industry members who participate in the development and updating of the standards. The committee forms the voice of all interested stakeholders including industry. It is an ongoing process, receiving feedback, comments, and issues. If the standard is already published, feedback can be communicated to API's industry representatives who then pass the information along to the committee chairman for discussion at the next committee meeting. If the committee is no longer active, API maintains a small group of individuals responsible for collecting and addressing inquiries and feedback from industry.

API has a quality management system which tracks and updates their standards setting process. All API standards are subject to review every five years. As part of this review, API frequently checks on all of the standards that they have active to see what their status is and if they have any questions or comments from industry that need to be addressed. Part of the five-year review is making sure all comments from industry are addressed, or at least discussed (John, American Bureau of Shipping Oil and Natural Gas Senior Engineer, 2014).

While API does not appear to collect probability or other scientific studies of guidelines effectiveness, it would be fair to say the degree to which guidelines from API do what they are supposed to depends on how closely they are followed by industry.

4.3.1.4 *Outcomes*

As the figures show in Section 4.3.1.1, the primary outcome of the failure reporting aspects of various API standards is to report to a manufacturer. This process recognizes the importance for OEMs to become aware of a deficiency within their product. With this data, OEMs may redevelop or revise its product or process and provide it back to the industry member. By providing OEMs with information on the failure through the processes outlined within the API standards, industry members are reducing their own liability and requiring OEMs to ensure products and services that meet the necessary requirements. Since the ultimate goal of the reporting is the reduction of the recurrence of the same incident, it is important for all stakeholders involved in a critical piece of equipment to be aware of the failure.

4.3.1.5 *Data*

Each company implementing the API standard would need to apply the standards to their operations. The standards provide a common template for implementation, but each company may interpret and implement the standard as it might apply.

API standards tend to either be component-specific or broad and general. Due to the variation and the differences in configurations and equipment from operator to operator, and even from rig to rig, the standards are applicable across the industry or for a very specific item. Due to this, the data collected may be differently applied or provide specific information pertinent to the OEM. Data collected is owned and managed by the company and can be shared with the OEM. There is no mechanism for reporting data back to API or to a regulatory body. Data can be shared at API meetings and during the standards development, which can allow for cooperative development to address common issues or program areas.

4.3.1.6 *Liability*

Since API standards are voluntary and provide standards that meet or exceed legal requirements, API will, most likely, not be held liable in case of a failure of an operator's failure reporting system. Given API is setting a standard, the liability of compliance will be on the operator to implement the guidelines and parameters provided in the standard.

The effectiveness of API failure reporting systems seems mixed. SME interviews suggest that while API standards are commonly adhered to, adherence is more common under some circumstances. Specifically regarding oil well drilling vessel practice in the Gulf of Mexico, one SME reported common industry practice as the following:

> If there is a risk of pollution or loss of well control the vessel will first gain control of the situation. They will then contact the appropriate governing bodies of the incident. The drilling vessel will then contact the OEM and other vessels to find out if this has happened elsewhere and complete an internal investigation. They will try to find out

> how to prevent this from occurring again. So the vessels will not keep anything secret and will report everything if there is a risk of pollution, loss of well control, equipment failure, personal injury or casualty (SME, 2014).

However, in the event of non-critical equipment failure, reporting seems more discretionary under current API voluntary guidelines. In addition, for subcontractors, such as drilling contractors, failure reporting appears highly driven based on client needs. Industry standards may play a secondary role to immediate financial concerns when non-critical issues are considered (SME, 2014) (Executive S. E., 2014).

While API guidelines do a good job tailoring standards to the realities of industry practices, there have been recent historical examples where API guidelines have failed to prevent equipment failure. Further review indicated that although API had provided relevant guidance for undersea connectors, the relevant suggested guidelines (Specification 16A) did not contain material property requirements for connection bolts used for subsea activities (Boman, 2014).

If an owner or operator implements an API standard, this can be used to show enhanced compliance and going above the minimum requirements set by regulation. While this does not exonerate the company, the use of API standards can show a good-faith effort in reducing risk and improving the safety of the operations. API would have little to no liability, since the organization is simply providing a voluntary standard that should represent the best practices and safety improvements, if implemented. If an issue arises where a failure occurs directly due to the implementation of the standard, API might be held liable; however, the collaborative and consensus-building approach to developing standards would allow API to shift liability to the industry members providing the feedback during the development of the standard.

4.3.1.7 *Applicability to BSEE*

ABS Consulting's review of API's failure reporting standards suggests at least two areas of weakness which BSEE regulatory action could address: the lack of an industry-wide failure reporting data repository and the lack of scientific methods of assessing API failure reporting systems.

First, there does not currently appear to be a comprehensive industry-wide failure reporting data repository. All of the failure reporting systems reviewed in this analysis are enterprise specific in that they largely confine information sharing to OEMs and the equipment using community. None of the failure reporting systems reviewed in this report contained a feedback loop incorporating organizations other than the user/operator, the manufacturer or associated subcontractors. There is no role for regulatory agencies, classification societies or academic think tanks.

Second, the lack of a scientific method of assessing the effectiveness of API failure reporting systems is an area that BSEE should consider addressing. The use of a SME consensus system does little to address the issue of participant bias and the impact of the use of consensus based voting process on actual failure rates has not been robustly and thoroughly evaluated using scientific methods.

4.3.2 International Association of Drilling Contractors

The IADC is the industry association representing the petrochemical drilling industry. Operating since 1940, membership is open to any company involved in O&G exploration, drilling or production, oil well servicing, oilfield manufacturing or other rig-site services. IADC members own most of the world's land and offshore drilling units and drill the vast majority of the wells producing the planet's O&G. The IADC has a number of functions including advocacy, education, standards development, training, industry coordination, accreditation, and publishing roles.

4.3.2.1 Information, Policies, and Procedures

The conception of the IADC's "Near-Miss" failure reporting began in 2012 when the USCG and the IADC had a series of exchanges in which the USCG requested information on the failure of critical systems. The final letter from the USCG to the IADC acknowledged that while BSEE was receiving reports on "information regarding malfunction or activation of the emergency disconnect system," (International Association of Drilling Contractors, 2012) they still wanted reports on near-miss incidents. The letter asserts that USCG and BSEE would cooperate in order "to coordinate the reporting of critical system failures" (United States Coast Guard, 2012). On 9 October 2013, in response to BSEE's Confidential Near Miss Reporting System initiative, the IADC announced a Drilling Near Miss/Hit Report.[12]

The IADC defines a Near-Miss as "all incidents that, if under slightly different circumstances, would likely have had potential to result in the following on an installation, vessel or aircraft:

- An occupational injury/illness which could be classified as at least a lost/restricted workday injury;
- Unauthorized discharge or spill;
- Hydrocarbon release;
- Fire/explosion; or
- Major impairment/damage to safety or environmentally critical equipment (International Association of Drilling Contractors, 2012).

The IADC has just recently produced a report for near-miss incidents on well-servicing and workover. The drilling industry can fill out this report on IADC's website and choose for IADC to include the information in a publically available Safety Alert report. If the information is used in the Safety Report, then the company's name and other sensitive details will remain anonymous once published.

The IADC has a nascent failure reporting system which utilizes INFOStat's RIMDrill software. While IADC is still finalizing their data reporting requirements for failure reporting, the ABS Consulting review did yield some useful information.

According to the IADC, a proper incident report provides:

- A summary of the incident reporting and investigation arrangements;
- Details of the potential incident criteria that is used;

[12] Completed in 2014, this report is available for purchase through the IADC bookstore.

- Information on the training provided for incident investigation team members;
- Information on the methodology adopted to identify incident causes; and
- A description of the arrangements for tracking action items arising from investigations to completion (International Association of Drilling Contractors, 2014, pp. Section 6, Page 4).

Although the IADC attempts to compile information on incident criteria and proper response, the association's request for such criteria as "methodology adopted to identify incident causes" indicates that the IADC has not employed a standardized system for incident reporting on a ubiquitous scale. The guidelines bulleted above prompt the contractor to submit a description of the process as it is executed, instead of confirming that the process was completed appropriately. Moreover, a uniform failure reporting system is not mentioned, reinforcing our finding that while the IADC has a method for failure reporting, but it still has not addressed how to overcome the hurdles presented by varying international regulations and policy.

An IADC-hosted Well Control Committee Meeting in May 2014 (after the publication of the current guidelines) explicitly discussed this issue. The committee noted that: "We think we know what the critical information is, but we have not pursued a standard method/format for reporting failures. A standard failure report form is needed. There is an excellent failure-reporting system, but we don't take the data and compare it in all the right ways. We need to be able to compare failures to real-time data about the system's use" (International Association of Drilling Contractors, 2014).

Infostat's RIMDrill software appears to be the sole reporting system to which IADC members submit data on operations and occurrences. RIMDrill exists in two editions: Onshore and Offshore, of which the offshore package is the more comprehensive. Daily Report and IADC Report forms are available through this software, as well. Unfortunately, no pricing on the various software packages is listed on Infostat's website.

To be more specific, RIMDrill offers "a broad range of rig and operational data, including tour data for the IADC report, [which] is entered into the rig site RIMDrill system. At the end of the reporting day, an officially approved IADC Daily Drilling Report is created and a copy of all entered data is sent to a central RIMDrill system in the office using the built in communications module.[13] This data is then available for automated distribution to all stakeholders or for those who need direct access to data using the RIMDrill interface" (Infostat, n.d.).

[13] To see an example of an IADC Daily Report or a RIMDrill report, see the IADC's website: http://infostatsystems.com/drilling-contactors-rimdrill/rimdrill-for-drilling-contactors.

4.3.2.2 *Elements, Best Practices, Lessons Learned*

Data generated from IADC Safety Alert reports have been used by the equipment manufacturer to redesign equipment specifications. For example, a Safety Alert issued in May 2009 (Alert 09-13 located in Appendix C) states how five employees suffered major injuries due to the failure of a 35 ton sheave used in a pulley system while lowering a heavy load. The report states that the incident was partly caused by the addition of another shackle to the pulley system, resulting in misalignment and ultimate equipment failure. As a corrective action, the equipment manufacturer redesigned the pulley rig stating, "The rig has been through extensive repair, redesign, and recertification by the manufacturer. All design issues and the rig documentation were revised by the manufacturer" (International Association of Drilling Contractors, 2009).

In addition, a Safety Alert issued in January 2014 (Alert 14-01 located in Appendix D) states that two employees suffered non-life threatening injuries after a dramatic increase in temperature and pressure within a Composite Air Pressure Vessel (CAPV) caused an explosion and subsequent pipe rupture. As part of the corrective actions taken by the drilling company, the OEM was brought in to assist with the incident investigation. Following the investigation, the manufacturer modified its equipment specification by recommending "a cool down cycle while filling the CAPV bottles with air" (International Association of Drilling Contractors, 2014). While the manufacturer did not make a design change to its equipment, it did modify the procedure in which the equipment is used in direct response to incident described in the IADC's Safety Alert 14-01.

4.3.2.3 *Role of Industry*

As mentioned above, the IADC's Safety Alert failure reporting is both created and referenced by private companies in the drilling industry. Since the failure reporting is anonymous, we did not obtain the individual company names from our research. The IADC also uses these reports to update its Health, Safety, and Environment Case guidelines. The Safety Alert program was implemented in 1998 and all Safety Alerts from 1998 through the present are available to the public via IADC's website.

4.3.2.4 *Effectiveness*

The IADC has an Incident Statistics Program, in which data on lost time and recordable incidents are regularly compiled into an annual report that summarizes this information based on geographical region. With the assumption that this data is obtained from the RIMDrill IADC Reports discussed earlier, company anonymity is mostly preserved. While the report does not break down incidents company-by-company explicitly, a prior knowledge of the companies working in each specific geographical area could lend some indication of who is recording these incidents. The IADC notes, "participation in the Incidents Statistics Program (ISP) is voluntary and open to all Drilling Contractors. However, a company must participate in the IADC ISP program and be a member of IADC in order to qualify for rig/unit recognition" (International Association of Drilling Contractors, 2014).

The ISP does record incidents in terms of equipment malfunctions, but does not discuss environmental incidents. Noted previously the inclusion of environmental incidents varies case by case. As the specific details of the IADC failure reporting system are not known at this time, further research is needed to provide an assessment of its safety and environmental incident reporting.

For the purposes of compiling the annual ISP report, necessary data includes: lost (work) time and total recordable incidents in terms of month, occupation, body part, incident type, equipment, operation, location, time in service, and time of day. For the failure reporting system, a Safety Alert should contain the following data: what happened, what caused it (the failure), and corrective actions taken. Photos, drawings, or diagrams are not required but encouraged to better depict the failure mechanisms involved (International Association of Drilling Contractors, 2014).

Near-misses do not fall under the category of incidents, therefore information or data could not be found through the ISP. The USCG and the IADC indicated that near-miss reporting to BSEE was confidential and voluntary, but the actual structure of the system developed is unknown at this time (United States Coast Guard, 2012).

4.3.2.5 *Outcomes*

Based on Task 2, regulators analyze Health, Safety, and Environmental case outcomes on a pass/fail or accept/reject system, namely that the case meets that regulator's specific requirements. While there is insufficient information available to develop a flowchart that traces the Health, Safety, and Environment case to the OEM, the flowchart shown in Figure 18 below depicts how the Health, Safety, and Environment case is an integral part of the drilling design and planning process. For IADC's failure reporting, our research did not discover sufficient information to create a flowchart of the incident back to the OEM; however, the Safety Alerts mentioned in a previous section provide examples of how the OEM modifies the design of a product directly due to an incident reported in the Safety Alert.

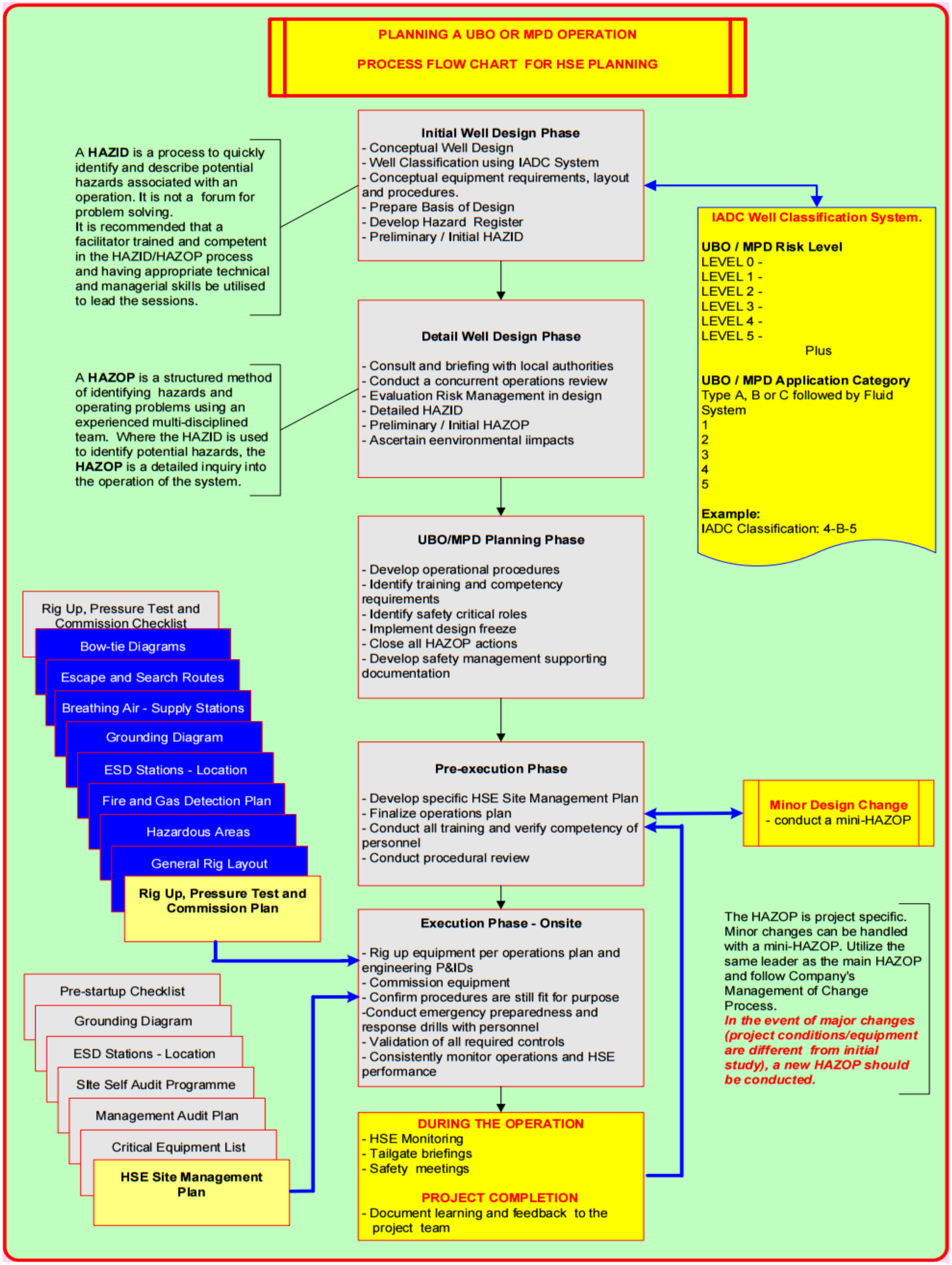

Figure 18: HSE Planning Process Flowchart

4.3.2.6 *Data*

Data for the IADC programs appear to come from two places: the Safety Alerts created and the ISP. The Safety Alerts provide examples in which the equipment manufacturer uses the information from the report to improve either the design of the equipment or specification in which it is to be safely used. IADC manages an ISP that tracks the frequency and incidence rate for lost time on the job due to safety related occurrences.

According to IADC's Five Year Summary Report, the incidence and frequency rate of reported lost time for the industry as a whole has decreased significantly from 2009 (FREQ = 1.88, INCD = 0.37) to 2013 (FREQ = 1.29, INCD = 0.26) (IADC, 2014) (refer to Appendix E). The use of IADC's Safety Alerts and other Health, Safety, and Environment measures has aided in the reduction of these rates and an overall increase in safety for the drilling industry.

4.3.2.7 *Liabilities*

Since the IADC does not set regulations for the drilling operators or drilling industry in general, our research did not uncover any evidence leading us to believe that the IADC’s failure reporting would make it liable for drilling-site incidents. Our research did indicate, however, that liability, resulting in injury or loss of money due to lost production time, falls primarily upon the drilling company or OEM.

4.3.2.8 *Application to BSEE*

Overall, the IADC provided a very comprehensive set of guidelines that delineated health, safety, and environmental cases for drilling contractors. Their international clout is evidenced by the regulatory bodies which hold these guidelines as a requirement. The IADC allows for a certain level of flexibility in tailoring the Health, Safety, and Environment cases for specific operations of varying scales, and in doing so promote efficiency and avoid redundancy and unnecessary paperwork. The crucial drawback is that these guidelines only have a binary measure of success. The biggest improvement would be to introduce a more widespread measure of success for cases in order to promote higher standards of execution and encourage more effective practices.

We recommend that BSEE consider incorporating and developing a form of the IADC’s ISP to better track equipment failures and reliability, instead of lost time and injuries from lessee incidents. Using such a program will help BSEE develop trends over time as well as judge the effectiveness of its regulations over time. However, as the IADC’s ISP does not account for environmental issues, BSEE would need to modify this failure reporting program to adapt it to their own needs.

4.3.3 International Organization for Standardization

The ISO is an independent, non-governmental organization with 165 member countries and a Central Secretariat based in Geneva, Switzerland. ISO has published more than 19,500 International Standards, which provide specifications for products, services and systems to ensure quality, safety, and efficiency (International Standardization Organization, 2014).

4.3.3.1 *Information, Policies, and Procedures*

Failure reporting is mentioned in ISO literature in a number of recommended standards, including ISO 14224 – reliability maintenance data,[14] ISO 9001 – Quality Management System Requirements and ISO 13533 – Specification for Drill Through Equipment.[15]

ISO 14224 – Collection and Exchange of Reliability Maintenance Data for Equipment

ISO 14224 refers primarily to the collection and exchange of information for petrochemical equipment. While its primary focus is on specifications for reliability main data systems, ISO 14244 does address Reliability Maintenance (RM) reporting systems, including data on equipment failure. ISO 14224:2006 provides a comprehensive basis for the collection of RM data in a standard format for equipment in all facilities and operations within the petroleum, natural gas and petrochemical industries during the operational life cycle of equipment.

ISO 14224 describes data-collection principles and associated terms and definitions that constitute a standardized "reliability language." ISO 14224:2006 also describes data quality control and assurance practices to provide guidance for the user.

In particular, ISO 14224 calls for failure reporting data systems to contain the following:

1. Identification data: failure record number, related equipment that has failed.
2. Failure characterization data: equipment data, failure date, items failed, failure impact, failure mode, failure cause and, failure detection method. Maintenance data including repair actions, resources used, maintenance consequences and downtime information.
3. Uniform definitions and classifications of failure which are standardized within and across enterprises.
4. Minimally burdensome standardized reporting.
5. Guidelines for the exchange and merging of [RM] data between plants, owners, manufacturers and contractors.
6. Minimum standard data requirements for failure reporting analysis (International Organization For Standardization, 2007).

ISO 9001 – Quality Management Systems Requirements

While ISO 9001 does not utilize the wording "failure reporting,", significant parts of ISO 9001 pertain directly towards failure reporting processes. In particular, Sections 5.5.2 and 8.2.3 both address management and organizational actions which pertain to organizational monitoring and control of business processes. These are the relevant portions of ISO 9001:

[14] ISO 14224 is identical to API/ANSI 689. For brevity sake this source is only included under the discussion of ISO standards.

[15] ISO 13533:2001 is identical to ANSI/API 16A. For brevity sake this source is only included under the discussion of ISO standards.

Section 5.5.2 Management representative

Top management shall appoint a member of the organization's management who, irrespective of other responsibilities, shall have responsibility and authority that includes: a) ensuring the processes needed for the quality management system are established, implemented and maintained, b) reporting to top management on the performance of the quality management system and any need for improvement….

Section 8.2.3 Monitoring and measurement of processes

The organization shall apply suitable methods for monitoring and, where applicable, measurement of the quality management system processes. These methods shall demonstrate the ability of the processes to achieve planned results. When planned results are not achieved, correction and corrective action shall be taken, as appropriate (International Organization for Standardization, 2008).

In Sections 5.5.2 and 8.2.3 of ISO 9001, failure reporting system components are strongly implied. Notably, ISO mandates management oversight of quality, as well as formalized monitoring and corrective action when planned results are not achieved – both of which speak to the basic feedback process implied in failure reporting.

ISO 13533 (Modified) – Petroleum and Natural Gas Industries – Drilling and Production Equipment – Drill-through Equipment

ISO 13533 outlines some basic parameters for failure reporting. Briefly summarized, ISO 13533 calls for a multistep failure reporting process. First, in the event of failure or malfunction, operators of drill-through equipment should provide a written report to the OEM. This report should contain as much detail as possible regarding the operating conditions at the time of the failure/malfunction, as well as an accurate description of the malfunction/failure (International Organization of Standardization, 2014).

Second, ISO specifications call for manufacturers to engage in both internal and external reporting. For internal reporting, all significant problems during manufacture, testing, or use should be formally communicated to persons responsible for design in the manufacturer's organization. Manufacturers are also required to report all significant problems and associated design changes to equipment operators within six weeks and 30 days of identification and remediation respectively (International Organization of Standardization, 2014).

4.3.3.2 *Elements, Best Practices, Lessons Learned*

Failure reporting systems are recommended as part of ISO-issued guidelines even if they are not labeled using the term "failure reporting system."

Much like API, ISO standards are voluntary and also use a similar consensus-based approach to standards development. Additionally, because ISO is an independent, non-governmental agency, the standards are not prescriptive and usually general in nature. This also means that the standards may not specify any possible software, data types, or transmission formats to use and will leave those decisions to the end user.

ISO continually updates it failure reporting documentation. ISO standards are typically developed or updated on an "as needed" basis, that is, when industry or ISO working committee participants indicate a need for them (International Organization for Standardization, 2009). For example, ISO 9001 is now being updated for 2015. An example of a failure reporting process as it relates to ISO 13433 is found in Figure 19 below.

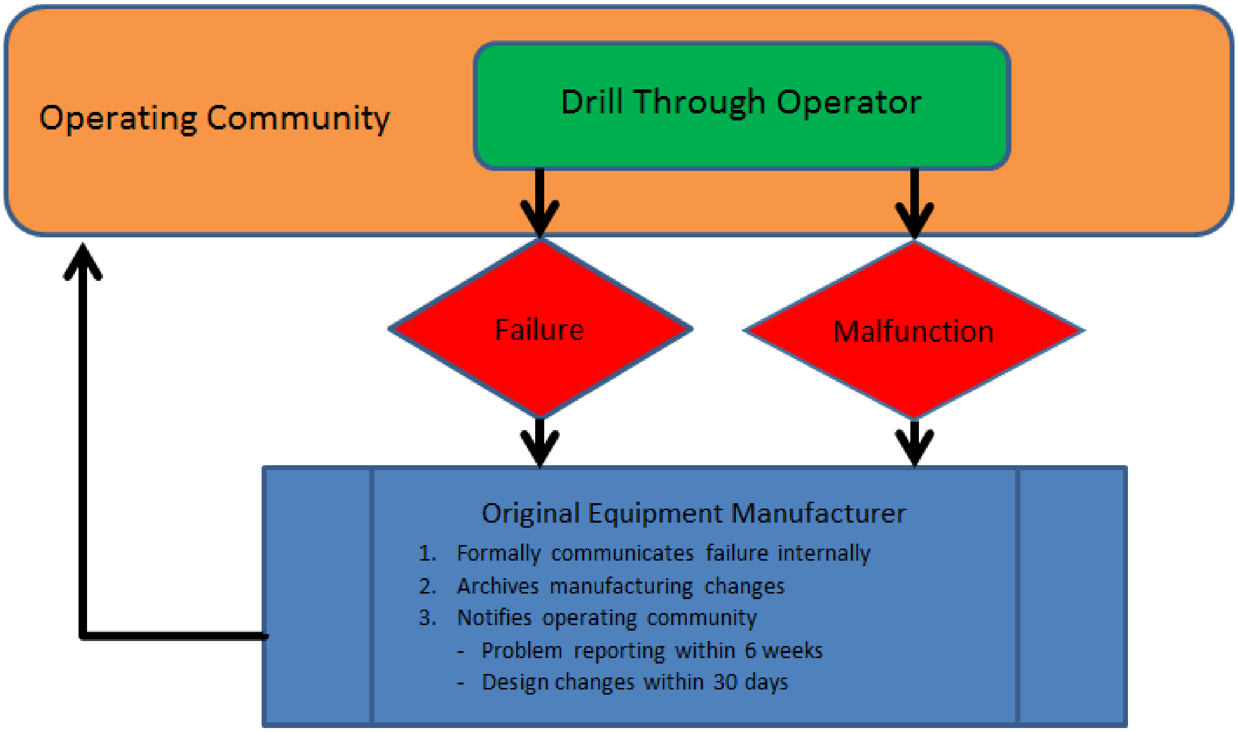

Figure 19: ISO Failure Reporting Process ISO 13533 – Specifications for Drill Through Equipment Flowchart

4.3.3.3 *Role of Industry*

ISO is an organization whose explicit goal is the setting of relevant industry standards. ISO periodically updates their guidelines to incorporate changing business needs and safety considerations (International Organization For Standardization, 2014). While not stated explicitly, the review process adjusts for the potential unpopularity of standards, as well as levels of satisfaction among the SME communities developing standards as understood by their quote of "ISO makes optimal use of the resources entrusted in it by its stakeholders by only developing standards for which there is a clear market requirement" (International Organization for Standardization, 2009).

4.3.3.4 *Effectiveness*

Because the standards under ISO are voluntary, it is difficult to actually measure their exact effectiveness. One measurement could be determining the number of regulatory bodies using the guidelines set by ISO when creating policies. Taking this idea a step further would be to measure incidence data reported to those regulatory agencies that had enacted ISO standards.

Since much of the ISO standards overlap and may be derived from API standards for the O&G industry, the effectiveness of these standards are muted, but do provide an equivalency and overlap between the U.S. and other countries. ISO standards that pertain to process management and other non-O&G-specific areas can be effective in improving the documentation of the processes. This documentation can improve the safety of operations and provide additional data on the effectiveness of an operation.

4.3.3.5 *Outcomes*

The overall outcomes of ISO standards are difficult to isolate. As mentioned previously, the best way to attempt to isolate the effectiveness and outcomes of an ISO standard may be to correlate which regulatory bodies decided to enact regulations that are based off of the ISO standard. Another potential method to determine the outcomes of ISO standards would be to measure the related incidents of an industry member that chose to implement an ISO standard.

Many regulatory bodies look to the ISO as guidelines for establishing their own policies. Additionally, many industry members and companies, including ABS Consulting, implement ISO standards. The adoption rate for ISO standards can be viewed as a method of evaluating effectiveness of their standards. Even though the standards are considered voluntary, industry members and regulatory bodies find them to be comprehensive and helpful to the organization that the industry member will proactively adopt the standards into their own policies.

4.3.3.6 *Data*

ISO does not appear to have any formal feedback or industry-wide method of evaluating their recommended failure reporting standards. ABS Consulting SMEs did not indicate that regular formal effectiveness or satisfaction surveys are a part of communications or outreach from these organizations. As mentioned previously, ISO standards are developed and updated based on what is occurring within the industry and what the needs are. Based on this, ISO would look to various data to determine where changes in their standards may be needed or what those changes would entail. Additionally, ISO would also look to data to determine where new standards may need to be developed (International Organization for Standardization, 2009).

4.3.3.7 *Liabilities*

Because the standards under ISO are voluntary, there is minimal liability towards ISO. The liabilities towards industry members and regulatory bodies that enact the standards and guidelines may still apply. As mentioned previously, ISO does routinely update their standards based on current policies, practices, and applications. This means that while there is not a liability issue to ISO directly, they stay involved in trying to reduce the risks and liabilities that may be associated with their standards.

4.3.3.8 *Application to BSEE*

Because ISO regularly updates their standards based on the current environment of the industry, BSEE regulatory updates should consider a systemic mechanism for regularly incorporating industry feedback.

Because ISO is international versus a domestic organization like API, BSEE can ensure more uniform compliance with international regulations and standards by adopting ISO standards. Incorporating these industry standards is a first step in increased participation and engagement in failure reporting by the industry.

4.3.4 Industry Representative Companies

ABS Consulting spoke with industry members who come from the large O&G industry companies. These organizations uniformly stated the use of LCM and failure reporting as part of their integrated SMS. Though no specific failure reporting process could be identified for the Industry Representative Companies, ABS Consulting was told most, if not all, large O&G companies employ some form of an integrated failure reporting process with their LCM system; however, most small or independent O&G companies might not use a failure reporting system and have a "run things until they fail and then fix it" philosophy. This philosophy stems from a couple issues: smaller companies typically do not have the manpower, financial resources, or desire to manage a failure reporting system. Specific information learned during the Industry Representative Companies interviews can be found in the Task 2 Report.

For brevity purposes and due to the failure reporting system being an integral part of Industry Representative Companies' LCM process, this section will refer to the Task 2 report for specific research findings.

4.4 Software

ABS Consulting reviewed failure reporting systems that are commonly used throughout industry either in the U.S. or internationally. In most cases, particularly in larger organizations, some form of failure reporting is used; however, many entities have developed a company-proprietary system which is custom-built for their organization.

This review excluded proprietary commercial systems or systems developed by regulatory agencies. Given the custom-build nature of many of the current software solutions already in use, ABS Consulting focused on commercially available software packages that broadly provide a software solution. We are aware other software providers may be available; however, we did not review them. Our review identified four commercial available software packages that have broad market penetration in the U.S. and internationally and may be of relevance to BSEE:

i. ALD Services – *FRACAS* Software
ii. IBM – Maximo
iii. PTC – *Windchill* – Product Lifecycle Management Software
iv. ReliaSoft – XFRACAS

4.4.1 ALD Services – FRACAS Software

ALD Limited is an organization dealing in Reliability, Safety and Quality Solutions (both services and software tools). ALD offers software solutions for Reliability Engineering, Reliability Analysis, Risk Analysis, Failure Analysis, Safety Analysis, Fault Tree Analysis, Event Tree Analysis, FRACAS and Life Cycle Costing, including Reliability prediction tools, Safety management and Quality management systems.

4.4.1.1 *Information and Procedures*

FavoWeb FRACAS software is used in the aerospace, defense, electronics components manufacturers, and telecommunications industries. ABS Consulting was unable to reach a U.S. representative (SoHaR, Inc.) to determine baseline costs; however, it is known that costs are dependent on the number of users, number of software licenses purchased, and specific configuration requested by the user company. User feedback on this product is overall positive and historically, based on user feedback, has performed well.

4.4.1.2 *Use*

FavoWeb FRACAS is a web-based and user configurable FRACAS that captures information about equipment or processes throughout its life cycle, from design, production testing, and customers support. FavoWeb FRACAS is an integrating tool which enables any organization engaged in design, manufacture, operation or maintenance of complex equipment to create one data repository for failures/incidents and repair data, thus achieving a clear picture over product reliability, safety, suppliers quality and customer suggestions.

FavoWeb Failure Reporting, Analysis and Corrective Action System are a modifiable off-the-shelf solution that efficiently overcomes all challenges of incident prevention by:

- Ensuring sufficient data collection;
- Timely monitoring of incidents;
- Providing means of cross-organizational incident management; and
- Predicting and preventing incidents/faults following in-depth analysis. (ALD, 2015)

4.4.1.3 *Liabilities*

Liability for use of the ALD FavoWeb software lies with the purchasing organization for its use and application. Installation, technical support, upgrades, training and warranty issues are the responsibility of ALD Services. There is no government liability for the use of the ALD FavoWeb software if an industry organization chooses to use this application.

4.4.1.4 *Application to BSEE*

This patented integrated web-based FRACAS software is similar in all respects to the other failure reporting software researched for this project. If this failure reporting software solution performs as advertised, it would be an effective tool that is directly applicable to the BSEE mission requirements. This may be a commercial off-the-shelf solution to BSEE's failure reporting system requirements.

4.4.2 International Business Machines MAXIMO Asset Management Software

The Maximo Asset Management Solution is an IBM enterprise asset management software product designed to act as a single point of interface for all aspects of an asset-intensive industry's facility infrastructure. Common industries which use Maximo include: utilities, O&G, pharmaceuticals, rail and transit, heavy manufacturing, airports, education, and the hospitality industry.

4.4.2.1 *Information and Procedures*

The software is specifically geared toward the oil and natural gas industry and is marketed as supporting ISO 14224 Failure Mode Effects Analysis and FRACAS Processes (International Business Machines, 2014).

Maximo has a number of features making it suitable for geographic and functionally diverse organizations. Since Maximo is designed as an enterprise-wide integrative software architecture, the cost to participate in IBM's Maximo has a large range. Costs vary depending on the amount of labor needed for installation, application development, user interface customization, data integration and migration, testing, and training.

Initial costs involve software licensing and associated fees. Costs start at $1,800 for a single software license (International Business Machines, n.d.). However, interviews with ABS Consulting SMEs indicate typical costs are significantly higher. Costs for a simple installation can range from $100,000 to $200,000 including software and basic work process documentation. If an entire energy enterprise has Maximo installed, the total value of work performed may exceed more than a million dollars. ABS Consulting SMEs indicate recent pricing suggests that enterprise-wide, full service Maximo implementation for a municipal power generating plant could cost between 10 and 15 million dollars (Venkatramam, Genesis Solitions Marketing and Sales Senior Director, 2015).

4.4.2.2 *Use*

This software is widely used and accepted as evidenced by the numerous worldwide user groups established. Industry has developed Maximo user groups throughout the world where organizations using the software can share lessons learned, best practices, announce meeting and conference dates, post agendas and share training practices. The Maximo Users Group has developed a web site, www.maximousers.org, where user group organizations worldwide can share information. The groups are either regional organizations (i.e., Pacific Northwest Maximo Users, Canadian Maximo User Group, Texas Maximo Users Group) or industry specific user groups (i.e., the Facilities Management Maximo Users Group and Maximo Utility Working Group) and all representative organizations licensed to use the Maximo software can join.

Some case studies suggest Maximo implementation may be non-straightforward, require extensive testing, and may not be suitable for work processes involving highly subjective material (Graham, 2012) (Raya Fidel, 2007) (Swinney, 2010). More recent software updates of Maximo require programmers with extensive knowledge of Java scripting to be able to update and customize the platform (Bhattacharyya, 2015). Finally, since Maximo has a high degree of functionality, it is sometimes not appropriate for small- or medium-sized businesses which cannot fully leverage the software's capability (Venkatramam, Genesis Solitions Marketing and Sales Senior Director, 2015).

4.4.2.3 *Liabilities*

Liability for use of the Maximo software lies with the purchasing organization for its use and application. The purchasing organization would be responsible for ensuring licensing agreements and software subscriptions remain in effect, if desired.

Installation, technical support, upgrades and training are the responsibility of the selling agent and IBM. IBM would be liable for all warranty related issues to include installation, parts repair and replacement, configuration and training. Failure of the purchasing organization to continue licenses and subscriptions agreements would relieve all liability from IBM.

There is no government liability for the use of the Maximo software if an industry organization chooses to use this software application.

4.4.2.4 *Application to BSEE*

ABS Consulting SME interviews suggest that use of Enterprise Management Software like Maximo has important implications both for regulatory oversight and business response to regulatory investigations. Notably, Maximo has a number of features which enhance transparency and accountability. For example, data elements in Maximo allow for improved chain of custody over records, documented work and repair history, as well as signature control over key data features. In addition, due to the structure of Maximo software (e.g., user interface overlaid over an object oriented database), records are retained in multiple locations making audits of business processes much easier (Venkatramam, Genesis Solitions Marketing and Sales Senior Director, 2015). This application is typically used by equipment or facility owners and operators for their entire LCM system and may not be an appropriate solution to BSEE's failure reporting system requirements.

4.4.3 PTC – Windchill – Product LCM Software

4.4.3.1 *Background*

PTC is a software development company founded in 1985. PTC services clients on six continents and has more than 28,000 customers. PTC Windchill is used in the Aerospace, Defense, electronics and high tech, automotive, industrial, retail and consumer, and life science industries.

4.4.3.2 *Information and Procedures*

PTC Windchill FRACAS software allows organizations to establish a clear, systematic way to address errors or incidents that occur within a product or system, develop and manage a plan of action to correct them, and ensure these processes have a positive effect on future performance. With this closed-loop corrective action process, organizations can track, analyze and correct problems found during development, testing and operation, with the goal of improving the reliability and quality of target products. This software allows organizations to identify trends related to failures and help prioritize the top issues to be addressed (PTC, 2015).

PTC Windchill FRACAS Features and Benefits

- Comprehensive management — Collect, quantify and control large amounts of incident reports to easily spot trends.
- Multiple user support — Easy access using a simple, intuitive, enterprise-wide web interface built on Microsoft Silverlight.
- Enterprise notification — Manages the business processes essential to root cause analysis and corrective action through workflow notifications and email alerts.
- Useful integration — Works seamlessly with PTC Windchill change management workflow (PTC, 2015)

4.4.3.3 *Use*

The cost of PTC Windchill is dependent on the number of users within the company and required licenses for the software. User groups have been established in 32 states, and 11 countries worldwide. These Regional User Groups (RUGs) share lessons learned, best practices, technical information and training ideas. PTC has developed the PTC/USER Portal, www.ptcuser.org, where organizations can find information about meetings, RUGs, join Technical Committees, and share information. User feedback on this product is overall positive and historically, based on user feedback, has performed well.

4.4.3.4 *Liabilities*

Liability for use of the PTC Windchill software lies with the purchasing organization for its use and application. Installation, technical support, upgrades and training are the responsibility of PTC. There is no government liability for the use of the PTC Windchill software if an industry organization chooses to use this application.

4.4.3.5 *Application to BSEE*

This software solution has the capability to track all products through all phases of the product lifecycle to include product performance and quality. This software can serve as a product LCM tool which includes the ability to track and evaluate failure reporting information, if required. This solution has the capability to manage product data, track product development to meet industry-specific requirements and it can support global product development. Because this software solution has failure reporting capabilities and can track and monitor product lifecycle, this product performs as advertised, this product is directly applicable to the purpose of the topics of this report. This may be a commercial off-the-shelf solution to BSEE's failure reporting system requirements.

4.4.4 ReliaSoft – XFRACAS Software

The FRACAS process itself has been around since the 1970s, developed by "defense and aerospace industries" as a way to standardize "the reliability and maintainability potential inherent in military systems, equipment, and associated software" (ReliaSoft, 2011).

On July 24, 1985, Military Standard 2155 was published in order to further "standardize the scope, definition and implementation of the FRACAS process." The document itself states, "the essence of a closed-loop FRACAS is that failure and faults of both hardware and software are formally reported, analysis is performed to the extent that the failure cause is understood, and positive corrective actions are identified, implemented, and verified to prevent further recurrence of failure." It defines a closed loop failure reporting system as "a controlled system assuring that all failures and faults are reported, analyzed (engineering or laboratory analysis), positive corrective actions are identified to prevent recurrence, and that the adequacy of implemented corrective actions is verified by test" (Department of Defense, 1985).

ReliaSoft advertises XFRACAS as a closed loop failure reporting, analysis, and corrective action system. Founded in 1992, ReliaSoft sells services and products, "dedicated to meeting the reliability engineering, quality, and maintenance planning needs of product manufacturers and equipment operators worldwide." It is not clear how long their XFRACAS software has been on the market, but the most current release is Version 9. XFRACAS is a "web-based … system, which facilitates incident reporting, failure analysis, part tracking, root cause analysis, team-based problem solving, action management, and other related activities" (ReliaSoft, n.d.).

4.4.4.1 *Information and Procedures*

From 2004 – 2014, ReliaSoft has sold various software packages to the National Aeronautics and Space Administration, the DoD (Army, Navy, Air Force), the Department of Commerce (the National Oceanic and Atmospheric Administration), the DHS (USCG), the Department of Energy, and the Department of the Treasury.

According to ReliaSoft, XFRACAS is designed to allow an administrator to grant permission to other members for access to certain data or functions within the system. As XFRACAS is a closed-loop system, the entire process of failure reporting and correction can be executed with its help, the final result being a report with the failure summary and relevant statistics that can be distributed as the administrator sees fit.

ReliaSoft asserts that XFRACAS was designed to help companies or agencies correct immediate problems quickly and effectively while also learning from their previous mistakes. ReliaSoft summarizes this by stating, "based on their specific permissions within the system, many different users at multiple locations can use a convenient web browser to report failures, incidents, issues and suggestions as they occur. They can also take advantage of convenient access to information contributed by other users." They emphasize the high level of usability of the software to enhance the avoidance of repeated mistakes factor. Namely, the failure analysis report, "gives a complete record of the organization's response to a particular failure and provides valuable data for troubleshooting, reliability analysis and other efforts" (ReliaSoft, n.d.).

ReliaSoft states that some of the most frequently captured details for XFRACAS include:

- Incident description;
- Priority and/or status;
- Date/time of the incident (and accumulated service, if applicable);
- Operating environment;
- Fault code(s);
- Troubleshooting efforts and incident resolution; and
- Is the incident a "failure" that should be considered in reliability analyses? (ReliaSoft, n.d.)

4.4.4.2 *Use*

ReliaSoft's XFRACAS software can be purchased by any company. The primary industries using the XFRACAS software are: aerospace, airlines, automotive, chemical and process, defense, electronics and appliance, energy, Information Technology hardware, medical and healthcare, military organizations, O&G, semiconductor, telecommunications, transportation, and trucks and heavy equipment. No information on cost is available or user-complied reviews of XFRACAS's performance. While additional research would be needed to address this, the fact that it has been awarded government contracts (41 in total) continually over the past decade indicates that ReliaSoft's programs perform adequately and are priced preferably over similar software programs from other companies.

The only substantial comparison research found on ReliaSoft's products versus those of its competitors was published in 2006 by the Society of Reliability Engineers. Discussing products offered by Isograph, Item Software, Relex Software, and ReliaSoft, the comparison does not make any recommendations, but instead presents readily comprehensible summaries and performable tasks by the respective software packages. XFRACAS specifically performs functions that fall under Reliability Management. Overall, ReliaSoft and its products were favorably reviewed. One distinctive feature noted was that ReliaSoft, "provides unlimited free technical support and minor software updates to registered users via phone, fax, email, and web meetings," whereas the other companies provided comparable support for only a few months (Willis, 2006).

While no explicit information on safety/environmental incidents could be found, the ReliaSoft site for XFRACAS states that a user, "can customize the Incident page (and all other XFRACAS user interfaces) to fit the specific preferences and needs of [an] organization. Interface text labels can be easily configured to match your existing internal terminology … [the user] can also add as many data fields as required to fit your data collection needs" (ReliaSoft, n.d.). Therefore, it may be possible that safety and environmental cases can be developed in XFRACAS at the user's prompting.

4.4.4.3 *Liabilities*

Liability for operational control, security and proper use of the software lies with the purchasing organization. Establishing the appropriate data fields and report generation would also be the responsibility for the purchasing organization.

Reliasoft would be liable and responsible for honoring all warranty details such as: proper installation, maintenance, to include part repairs and replacement, software upgrades, web-access, training and ensuring the XFRACAS software performs as designed and meets the standards of the purchasing organization's operational and administrative requirements.

As Military Standard 2155 is only a guideline and no longer a requirement, the legal liabilities of XFRACAS are unknown, regardless of how well it actually corresponds to that standard. Because there are no requirements for an organization to use a failure reporting system, if an entity chooses to employ failure reporting software such as XFRACAS, liability for its use and content would be the responsibility of the user organization.

4.4.4.4 *Application to BSEE*

Given the estimated sales and its numerous contracts with the government, ReliaSoft and its XFRACAS software appear to have use for both governmental and nongovernmental entities. This may be a commercial off-the-shelf solution to BSEE's failure reporting system requirements. When developing its own failure reporting system, BSEE may have interest in the most advertised features with XFRACAS, such as its web-based implementation, ability to work on multiple types of browsers, and purported ease of use. All of these factors enhance its flexibility, allowing greater access and, implicitly, greater group cohesion and cooperation when reporting, analyzing, and correcting failure.

5. Findings

From this agency and organization review, ABS Consulting has pulled together the overall and broad findings about failure reporting systems. We have applied the same agency review structure to our findings. ABS Consulting's review suggests that failure reporting systems are in use by regulatory bodies domestically and internationally. However, minor to extensive differences exist between the types of failure reporting systems, their degree of prescriptiveness, type of incidents they cover, and the historical institutionalization of these systems.

5.1 Information, Policies, and Procedures

The type of systems involved varies a great deal in their prescriptiveness and what kinds of incidents are covered. There are also common attributes across the various approaches. We have identified the following three trends:

1. U.S. regulators have prescriptive or semi-prescriptive failure reporting systems rooted in federal law which mandates reporting. The international regulators reviewed (The New Zealand Department of Labor, Norway PSA and UK HSE) have risk management requirements based on voluntary reporting requirements. The degree of difference between the prescriptiveness depends in part on the sector of the energy industry being regulated. Variables include the format of reporting, level of requirement, degree of verification, the amount of information required and the scheduling of reporting required.
2. Where failure reporting is separate from LCM, failure reporting is reactive. Since, LCM is about maintenance and preventive, when failure reporting is coupled with an LCM system, this allows for a blended approach: proactive measures to prevent failures, but still have the ability to collect, analyze, and react to a failure. For example, where the failure reporting system is merely a legally mandated requirement, separate reporting is almost always after the fact. Near-misses are typically not part of failure reporting.
3. Most failure reporting processes have more stringent reporting requirements for more serious incidents. For example, PHMSA requires an immediate report in the event of death or a hazardous materials accident costing more than $50,000, however, less serious incidents can be reported within 30 days. Similarly, language in the NRC indicates that multiple failure events require more immediate reporting by the nuclear plant operators.

The earliest failure reporting mandates in the U.S. date from the 1970s. Many agencies adopted failure reporting later in the 1980s and the requirements are dynamic. For example, the USCG's failure reporting system dates to 1985 but is continually refreshed, with the most recent update in 2013.

Many failure reporting software packages identified were designed with DoD as the intended client, or to be compliant with DoD's FRACAS process. Other software developers tend to be modeled for a specific industry like the RIMDrill program or process-focused like IBM Maximo which can be custom-built and tailored to the specific company. Members of the IADC generally use the RIMDrill program. RIMDrill is a "rig-to-office" software package that serves as the reporting system through which IADC members submit data on operations and safety and environmental performance. Since RIMDrill is used to provide reporting data to national regulators, ABS Consulting understands this software package is currently in wide use among offshore drilling contractors and operators.

In the UK, the oil and natural gas industry widely uses the RIDDOR failure reporting database due to HSE's mandating of the use of RIDDOR for organizations drilling in areas under the UK's jurisdiction.

In the U.S., many offshore operators make use of API and ISO standards for failure reporting. However, these systems tend to be industry-focused and emphasize failure reporting to enhance system performance and typically do not inform regulatory bodies or OEMs when failures occur.

Other software packages such as IBM Maximo and ReliaSoft's XFRACAS can be used by the O&G industry, but are more likely utilized only by larger industry actors because of the relatively high cost of purchasing and implementing asset management and failure reporting software systems.

ABS Consulting research indicates that almost all major industry actors in the domestic energy, pipeline, hazardous materials, maritime shipping, and offshore O&G industry have implemented failure reporting. Many energy industry participants have proprietary systems while others use commercially available software systems or follow API or ISO guidelines regarding failure reporting.

Industry failure reporting appears to focus primarily on equipment malfunctions/failures. This trend is especially evident in the guidelines promulgated by API and IADC. For API, the failure reporting with sufficiently detailed information reviewed pertained primarily to equipment malfunctions/failures. No reference to environmental incidents is included. A close review of the IADC ISP tells a similar narrative. The ISP does record safety incidents in terms of equipment malfunctions, but it does not discuss environmental incidents.

5.2 Elements, Best Practices, and Lessons Learned

As mentioned previously, failure reporting can be as simple as notification of a failure or can be part of an iterative and closed loop corrective process. A failure reporting system, at its most basic, is a model for identifying and making notification of incidents. A failure reporting system that includes the corrective action element can be a more complex model that includes identification and notification, but it also imposes additional requirements for investigation, mitigation, analysis, and on-going assessment by those making the report. The organizations reviewed in this report can be broadly assigned to one of these two models.

This distinction is important because it represents a choice that BSEE will have to make in the formulation of an effective failure reporting system. The model used by the USCG, PHMSA, and HSE is static and reactive and confined to reporting of failures. This model does not explicitly place the burden for corrective or preventative action on the owner/operator. Inherent in this model is the assumption that the owner/operator will take corrective action to prevent reoccurrence, but in no way are they compelled to do so as it relates to reporting. The models used by the DoD, NCR, PSA, New Zealand Department of Labor and IADC are dynamic. This model explicitly requires the owner/operator to investigate, mitigate, analyze, and perform on-going assessments of the corrective or preventive actions.

Assuming BSEE would be more attracted to a, “failure reporting corrective action system,” the following discussion will present a compilation of elements that encompass an effective failure reporting corrective action system.

Policies, Programs, and Procedures

A failure reporting corrective action system should include the expectations, requirements, and implementation processes in policies, programs and/or procedures. They should apply to and be uniformly implemented across the offshore industry.

These policies, programs and procedures should ensure:

- Roles and responsibilities regarding the failure reporting corrective action system are clearly defined.
- All employees are encouraged to identify and report failures promptly as they occur.
- Management is required to review regularly the status of failure reporting corrective action system.
- Incidents/near-misses of a similar nature are evaluated and resolved.
- Timely and appropriate identification and reporting of failures are:
    - Documented, tracked and assessed;
    - Investigated to identify:
        - Causal factors;
        - Root causes;
        - Contributing factors; and
        - Corrective actions.

Identification, Reporting and Documentation of Safety and Incidents

A failure reporting corrective action system should require management to routinely recognize and promptly report incidents in a manner that supports the timely and effective assessment of the issues.

The failure reporting corrective action system policies, programs and procedures should ensure:

- Employees are informed and aware of the requirement to identify and report failures and incidents. This may include regulatory reporting and compliance issues.
- Each reporting method promotes the collection and documentation of the type and quantity of information necessary to assess the incidents' significance
- The methods of reporting an incident are comprehensive and clearly define what issues should be reported and how to report them.
- An emphasis on reporting of issues at the lowest level and as soon as possible to ensure the resolution of the issues before they result in more significant problems.
- Reported incidents and the relevant information are appropriately documented.
- Communication of information to organizations and individuals affected by the incident.

Assessment and Causal Evaluation of Incidents

The failure reporting corrective action system should include a causal evaluation process that identifies incident causes, contributing factors and root causes of the incident. In addition, corrective actions necessary to prevent reoccurrence of the failure should be identified.

The failure reporting corrective action system policies, programs and procedures should ensure:

- An initial assessment of the actual or potential significance of the incident is performed to determine if immediate corrective action is warranted to prevent or mitigate an actual or potentially unacceptable consequence.
- The assessment procedure describes how to assess the incident.
- That a causal evaluation for significant safety incident begins as soon as possible to preserve evidence and data and to reduce the deterioration or loss of information.
- When appropriate, there is a feedback process to notify the OEM of potential defects with their products.

Development and Implementation of Corrective Actions for Each Incident

The failure reporting corrective action system should require the identification and implementation of corrective actions are timely and effective in preventing the recurrence of the same issue or the occurrence of similar safety incidents.

The failure reporting corrective action system policies, programs and procedures should ensure:

- Corrective actions are developed, prioritized, approved, tracked and completed in a timely manner.
- Corrective actions specifically address the contributing factors and root causes identified from the causal evaluation determination.
- The effectiveness of each corrective action is verified.
- Corrective actions are achievable and measurable.
- Individuals are assigned the responsibility for the corrective actions implementation, and establish a schedule for initiating, completing and implementing each corrective action.
- That management receives periodic briefings and reports on the status of corrective actions
- That a clear and comprehensive description of each corrective action is recorded, and this information is used to track and trend corrective action status to completion.

Assessment of the Failure Reporting Corrective Action System Effectiveness

A failure reporting corrective action system should require implementation of processes that enables it to identify and correct performance issues that reduce the system's effectiveness in the identification, reporting, assessment and correction of safety incidents and the prevention of similar incidents.

The failure reporting corrective action system policies, programs and procedures should ensure:

- When a corrective action has been fully implemented, the completion of the corrective action verifies the effectiveness in resolving the apparent contributing and root causes.
- Identified safety incidents and their associated causes are trended to assist in the identification of repeat occurrences.
- The trend data is periodically reviewed, analyzed, and summarized in a report, and disseminated throughout the organization as deemed appropriate to assist in review and follow-up.
- There is a formal assessment process that describes the elements and processes to be assessed and clearly defines acceptance criteria for determining effectiveness.

Best Practices

The following are some of the best practices that are common to many of the failure reporting corrective action systems reviewed. These best practices are not specific to any one system but include some of the following elements:

- A system that is structured for identifying, screening, evaluating, and correcting conditions that affect safety, reliability, quality, and regulatory requirements should be a key component of a LCM or SMS system.
- An effective system promotes efficient management and continuous improvement.
- Active monitoring of the system by management provides for continual system improvement.
- A system that encourages all employees to identify issues that affect safety, reliability, quality, and regulatory requirements is critical.
- A system that establishes identifying criteria for each type of incident can better categorize incidents when they occur.
- Fully developed systems are more effective at communicating the results of the investigations and corrective actions to avoid repeating similar incidents.
- Effectiveness monitoring and self-assessment of the systems will ensure the objectives of the systems are being met.
- Systems that set high expectations ensure the program is being used to improve safety, reliability, and efficiency.
- Employee training about the systems provides the best opportunity to preserve integrity.
- Accurate databases for a system ensure key activities are not lost.

Lessons Learned

As a general rule, offshore related accidents and incidents are mainly notified to national regulatory agencies based on national legislative requirements and gathered on a national level. As a result in most cases, the focus is given to accidents resulting in fatalities, injuries or serious damage to the installation.

Near misses are not always reported since this is not always a legal requirement. Some regulatory agencies publish reports on accidents with statistical data and lessons learned. But for most of the organizations evaluated for this study, accident descriptions are not available to the public. One of the key issues highlighted by this study is that there is no common formatting for failure reporting between different countries and different organizations. No common format is followed and even the definition of what constitutes a "reportable accident" varies amongst the regulatory agencies. For example, some consider one or more days of absence from work following an incident as a reportable event, whereas others require the absence for at least three subsequent days as the necessary condition. There is currently an effort by international associations like the International Regulators' Forum and the North Sea Offshore Authorities Forum to achieve common formatting for the reporting of accidents and incidents between different countries and different legislations. However, the overall picture of accident reporting looks like a puzzle: there are many pieces available, but it is very difficult to put them together in order to get the full picture (Christou & Konstantinidou, 2012). Never the less, there are some common key points from this study.

- Data is absolutely necessary for effective lessons learning and dissemination of knowledge on past accidents.
- Data is necessary in order to obtain a clear overall picture of the risk of possible accident types and to make risk management decisions.
- There is a clear need for pooling of data in order to have a complete picture of the safety in offshore sector.
- There is a clear need for common formatting of failure reporting in order to facilitate data and experience sharing.
- The inclusion of near misses in accident databases is necessary because important lessons can be learned from them.
- Lessons learned from accidents and incidents should be available to all stakeholders.

5.3 Role of Industry

For failure reporting processes, industry's role is often to identify the regulatory requirements (if any) established by the government agency responsible for managing and enforcing the laws associated with a particular program. Industry must determine the requirements within regulations that apply to their organization and structure their failure reporting system (if required) to meet or exceed the regulations.

For the O&G industry, larger industry organizations rely on industry standards like the ones developed by IADC, API, or the ISO for guidelines to use as a framework to develop failure reporting programs. These programs are voluntary, though they may be a condition requirement for membership. Internationally, if these standards are incorporated by reference in the regulatory framework, then the specific standards must be addressed when developing a Safety Case.

Often, failure reporting is incorporated as part of the regulatory mandates requiring the development of a SMS, or, in the case of the international regulators reviewed, the requirement for industry to develop a Safety Case.

Another important role of industry is communications. Reporting accurate information, as required by regulations, is vital in helping regulators make informed decisions across the industry on creating or modifying regulatory frame work to meet the needs of industry and regulators. The UK HSE's RIDDOR program requires the "Responsible Person" to report certain serious workplace accidents, occupational diseases, specified dangerous occurrences and near-misses. The RIDDOR database was one of the key sources of information used when the UK developed the KP4 program. In Norway, PSA manages a regulatory forum which allows industry to make substantial contributions to the direction of regulations and guidelines published by the PSA. Because these companies have been able to maintain PSA qualification to operate, it can be expected that all of these companies maintain systems that might provide proper failure data to the PSA.

5.4 Effectiveness

Of the domestic agencies reviewed for Task 3, the overall level of effectiveness[16] of failure reporting is mixed. ABS Consulting attributes this outcome due to the following reasons:

- *Federal Failure Reporting Programs are often threatened by resource constraints*. This theme has emerged in two of the agencies we reviewed, the USCG[17] and NRC. In both instances, staffing and resource constraints were noted to cause problems in evaluation and causal analysis. In short, Federal Agencies often do not have sufficient resources devoted to monitoring and controlling failure reporting data systems.
- *Underreporting can impact the quality of both public and private failure reporting data.* Notably, PHMSA estimates that approximately 80 percent of actual relevant instances of failure reporting are recorded in PHMSA data systems. This is partly due to difficulties in data recording procedures between state and Federal regulators, but also due to highway and motor carrier industry lack of reporting adherence. Other agencies reviewed did not speculate the level of compliance with reporting. PHMSA's 80 percent reporting may be higher and more accurate than other agencies.
- *Regulatory adequacy.* In some identified cases, regulations have been insufficient to prevent failures from occurring. This has particularly been an ongoing issue for PHMSA's regulatory oversight of DOT 111. In the case of USCG, CASREP can only show previous accident history, with no predictive ability to forecast future or new threats that may be emerging.

[16] In this case we take the meaning of program effectiveness to mean adequate to accomplish a purpose: producing the intended or expected result of all relevant incidents being reported to a Federal regulatory body.

[17] In 2013, an Inspector General's audit of the USCG failure reporting system found "*[t]he USCG has not developed and retained sufficient staff, ensured all corrective actions are addressed and implemented, and needs to enforce requirements related to reporting marine accidents consistently. As a result, it may be delayed in identifying causes of accidents; initiating corrective actions, and providing the findings and lessons learned to mariners, the public, and other government entities. These conditions may also delay the development of new standards, which could prevent future accidents.* (Marine Accident Reporting, Investigations, and Enforcement in the United States Coast Guard, 2013)"

- *Unclear language*. The effectiveness of ISO 14001 guidelines was hindered by unclear wording inherent in the language of the standard. This situation resulted in earlier versions of the ISO 14001 guide being less than optimally effective in environmental management.
- *Industry adherence challenges*. Interviews with ABS Consulting SMEs suggest that failure reporting are subject to a number of practical implementation difficulties. These include:
  - *Failure reporting imposed by government are often viewed as slow and producing information which is not useful for industry*. Quarterly, bi-monthly or annual reporting often is viewed as too slow by members of the energy sector to have any practical operational use.
  - *Mistrust.* SME interviews indicate that the oil and natural gas industry is competitive and mistrustful of regulatory agencies. This has a number of practical implications. First, SMEs indicated that industry subcontractors may feel concern that they will lose business if they report failures. Second, SME interviews also suggested that if failure reporting requirements are too closely tied to policy or regulatory initiatives, it will increase the underreporting rate to any involved system.
  - *Industry Segmentation*. SME interviews indicate that larger industry actors have more sophisticated management systems and are therefore more receptive to failure reporting. In contrast, smaller industry actors have fewer resources to devote to reporting and are viewed as less likely to report for this reason (Anonymous, 2015).

In a generic sense for Federal regulators, effectiveness or performance is typically measured by the absence of failure, or by the lack of detrimental outcomes such as deaths or property damage. In many instances, this is shown by the decline or reduction of measured incident reports. For example, PHMSA regularly publishes figures on the number of failures per million miles of pipeline, and typically shows the number of persons harmed during pipeline accidents on their website. NRC uses the LER as a tool for trending studies and to measure their own regulatory effectiveness. The LER is typically used to record non-emergent situations such as low risk mechanical failures, though the LER is not used to record emergency events such as the release of radioactive material. Similarly, the USCG employs a variety of effectiveness measurement targets to communicate the success of its prevention programs. The following are a few examples of these effectiveness measures:

- The five-year average number of commercial mariner deaths and injuries;
- The five-year average number of commercial passenger deaths and injuries;
- The five-year average of maritime injuries;
- The five-year average number of oil spills into the marine environment per 100 million short tons shipped; or
- The five-year average number of chemical discharges into the marine environment per 100 million short tons shipped (Independent Evaluation USCG Prevention Program, 2009).

Of the international agencies reviewed for Task 3, the overall effectiveness of failure reporting is mixed. Many of the international regulators use the Safety Case; each company develops and seeks government approval of their Safety Case. These regulations do not specifically require the development of a failure reporting system; however, some regulations may require the organization submit reports and make the program available for audit and review during inspections. Safety Case regulations do not stipulate requirements to track the effectiveness of individual organization's failure reporting. This also results in company-specific data, therefore determining industry-wide issues or effectiveness may be reduced.

Government regulator's primary concern, as it applies to failure reporting, is to ensure regulations and processes are in place and any data collected will have a direct impact on improving human health and safety and protecting the environment. In contrast to government, business process and cost concerns appear to play a greater role in failure reporting from industry organizations. For example, ABS Consulting's interviews suggest that for the offshore O&G industry in the Gulf of Mexico, business processes and cost is a greater concern for the effectiveness of failure reporting. That is to say, non-critical failures are more likely to be reported if there are immediate business process concerns (e.g., meeting deadlines) or profitability (e.g., loss of production or paying the high cost of drilling subcontractors). While metrics like failure, safety and number of accidents prevented is important for industry, industry failure reporting are likely to consider a failure reporting successful if it does not adversely impact business processes, production or profitability.

5.5 Outcomes

A central issue in failure reporting is the data. Data collection, data management, and data analysis are key in having a functional failure reporting system. Data provides the understanding of the impact of a regulation, but also to track the outcome of a process. Successful failure reporting systems should have clear inputs and outputs. While not directly regulating an industry, FHWA's HPMS has a standard data collection template that allows for aggregation across the different state departments of transportation. These collected data are used for decision-making on multiple levels, effecting future changes and development. Based on the known impacts of the data, this increases compliance and participation in the program.

For BSEE, publishing the collected data may be insufficient to produce a favorable outcome. This type of data publication is already being done by the Offshore Equipment Reliability Database (OREDA), thus a failure reporting requirement would need to show further benefit to both the industry and to the regulator. Data publication is a good preliminary or intermediary step. By having the data collected and published, it can act as a review stage to ensure the correct information is being collected, as well as to identify the main risks or hazards within the industry.

Publishing the data allows additional data analysis to occur. With the data, BSEE can conduct internal data validation and analysis to identify trends, but publication will also allow both industry and watchdog groups to conduct their own analyses of the published data. This can increase the useful and usable findings that can influence the outcomes of the incidents captured from failure reporting.

Collecting the data will allow for the identification of trends and top risks. USCG's failure reporting approach recognizes there are more areas to focus on and monitoring that can be done, thus focusing on the top issues to reduce the most risk is the best use of resources. By collecting the data, this can provide the initial step of risk identification in the risk mitigation process. BSEE can then focus on these high level risks and change the reporting requirements and regulatory requirements to adapt to these changes. If the output of the aggregated data is used as the input for data collection, BSEE should then ensure collecting and aggregating data to identify new or emerging issues that may occur. FHWA's HPMS data collection forms are informed by the outputs of the process, creating their seven high priority areas. This form is also reviewed and assessed on a three-year cycle to ensure the priority activity areas are the correct areas. In addition to FHWA, USCG uses an Update CASREP to refresh their CASREP data inputs.

Not all reviewed processes had manufacturer notification. ABS Consulting believes this to be a good practice to create effective outcomes. By having a manufacturer notification, this impacts failure reporting throughout the process from planning to operations to decommissioning. To notify a manufacturer, the data collection must allow for specificity of the manufacturer and the part. Looking at the USCG Incident Reporting process, when a failure occurs, the appropriate USCG office (USCG Office of Design and Engineering Standards [CG-ENG]) collects these data, identifies issues, and notifies the manufacturer of the issues for correction. CG-ENG then ensures these corrections are effective at addressing the issue while not introducing new issues. The manufacturer would then issue a notification or a recall to the industry, if necessary.

A key discussion point is what the outcome data could look like. In the API and IADC standards, there is a simple pass/fail or accept/reject option. The UK HSE further expands this option into six tiers with three groups to determine severity of the failure. A component failing may be a concern; however, if the failure results in a catastrophic loss, this should be categorized in a different manner.

Each process should create an actionable item as part of the process for improvement and data analysis. For USCG, reports captured are collected and used to identify trends, but also to notify the OEMs for their action. The process then requires action on the part of the OEMs to show to USCG their implementation of an improvement without compromising the equipment.

PHMSA outlines the process and the time requirements for each step. This provides a framework for understanding what they are supposed to be doing, but also, when they are supposed to be completing that action. This provides measurable standards for compliance and direction in the event of an incident. From these data, PHMSA should be able to measure the outcomes of the impact of the regulation and the process.

5.6 Data

Most of the failure reporting systems, database and guidelines reviewed do not appear to make a substantial accommodation for proprietary data. The objective of most of the failure reporting systems reviewed is information sharing, and thus relevant information on failures is widely available to the regulatory community, the public and industry actors. To illustrate this, we discuss the USCG's MISLE data and the Nuclear Regulatory Commission's LERSearch.

The MISLE database is the USCG's primary system for documenting marine casualties. MISLE has one of the most, if not the most, comprehensive collections of data regarding marine casualties in the world.

Only USCG authorized employees can access the database. However, the USCG does post some of the data collected from marine casualties in MISLE to the CGMIX website. The CGMIX website makes incident investigation reports available to the public in a searchable online database.

The NRC's LERs are non-proprietary reports that are accessible to the general public through LERSearch. They are not anonymous, as the company name, a point of contact, and the plant's location are all given in a completed LER. Even though the LER data does make provisions for proprietary data, access is shared with authorized contractors, even though "access is limited to NRC licensed utilities, NRC personnel, and authorized contractors." Authorized entities have access to CCFDB and accompanying analysis software, in addition to the Reliability and Availability Data System and analysis software. Therefore, all operators can benefit from both LER and proprietary data to improve performance and mitigate risk (Nuclear Regulatory Commission, 2015).

At least three mechanisms are utilized to maintain anonymity in reporting failures. The first mechanism is that several of the agencies reviewed reported only aggregate statistical data. UK HSE preserves anonymity when it publishes the annual statistical report. As this report does not make recommendations, it serves the purpose of a comparative year-by-year assessment as to how well its health and safety programs are working. Though all companies that participate have access to the annual report, the HSE may provide additional guidance and recommendations through other outlets to minimize incident occurrences.

The second is that many agencies provide restricted access to failure data or have confidentiality policies that limit disclosure. For example, the UK Health and Safety Authority has a confidentiality policy that states all data, "is handled, stored and accessed in a manner which complies with Government and Departmental standards regarding security and confidentiality, and fully meets the requirements of the Data Protection Act. Access to this data is controlled by a system of passwords, and strict business need access control. Disclosure control is implemented where deemed necessary to avoid the disclosure of personal information through statistical outputs, especially where small counts are involved" (UK Health and Safety Executive, 2014).

The third mechanism is that some agencies maintain anonymous reporting systems. A good example of this is the USCG's policy on near-miss reporting. As near-misses do not fall under the category of incidents, no information or data could be found through the ISP. The USCG indicates that near-miss reporting to BSEE was confidential and voluntary, even if the actual structure of the system they developed in their report is unknown at this time (United States Coast Guard, 2012).

For the offshore oil and natural gas industry, non-anonymous reporting can still be effective. Primarily because information that is considered proprietary would not necessarily be included in systems designed to evaluate hardware failure. Interviews with SMEs indicate that proprietary data about the exploration and drilling is largely confined to drilling and well completion techniques. SMEs report that regardless of the type of failure reporting system (e.g., mandated or voluntary) any information related to equipment failure, safety or petrochemical spill activity would very likely be promptly and accurately reported. The legal and financial liabilities associated with false or underreporting is too great (Executive, 2014) (SME, 2014).

Some data submitted by the industry may be specific to a company, given the uniqueness of layout, location of facility or vessel design, thus anonymizing the data might be difficult to achieve without rendering the data unusable.

However, ABS Consulting does note that industry SMEs did voice concerns regarding the issue of liability. For non-critical health, safety or business operations issues, SMEs felt that disclosure of a failure incident could subject the reporting company to legal or regulatory action, potentially undermining reporting rates (Anonymous, 2015).

While speculative, ABS Consulting believes that proprietary information is treated as much the same way as non-proprietary data. Both are used as inputs into existing failure reporting or LCM systems. An illustrative example of this is the IADC's use of RIMDrill to report failure incident statistics.

The IADC ISP compiles data on lost time and recordable incidents that go into an annual report that summarizes this information based on geographical region. This data is from the RIMDrill IADC Reports discussed earlier, and company anonymity is mostly preserved. The IADC notes, "participation in the ISP is voluntary and open to all Drilling Contractors. However, a company must participate in the IADC ISP and be a member of IADC in order to qualify for rig/unit recognition." (International Association of Drilling Contractors, 2014). IADC policy indicates that even if industry data is proprietary, it gets published in much the same manner as public data. Additionally, it seems the IADC can compel participation in their voluntary reporting system by making participation at least a loose requirement of membership.

Any failure reporting system should collect data that is sufficiently comprehensive to cover a wide range of possible analysis. All of the proposed data fields here are already recommended as part of API failure reporting guidelines and are measurable and capable of being easily stored in a data warehouse. At a minimum BSEE should include the following information as part of any failure reporting system for the offshore petrochemical industry:

- *Unique failure incident identifier:* For database management purposes, BSEE should assign a unique identifier to each identified failure.
- *Operator data*: Operator, name, field/area, lease name and well number, operator signature and date, operating facility type, whether subcontracting companies were involved.
- *Well data:* Well test rate, environmental conditions, percent sand, H_2S, CO_2, pressures and temperatures, surface, bottom hole, SSSV equipment settling depth and installation rate, time equipment is in service and presence of unusual operating conditions, well operating data: flow, percent flow rate Gas, Oil, H_2S, CO_2, percent sand, PPM chlorine, PPB oxygen, PPM mercury, PPM elemental sulfur, flowing and shut-in.
- *Facility data:* Information about the facility where failure occurred: including facility type and location (that is, whether drilling boat, offshore rig, type of rig, etc.).

- *Failure data:* Description of failure, nature of failure, latitude and longitude where failure occurred, observed conditions which could have caused failure, probable and secondary cause of failure, type of equipment failed: model, part number, manufacturer, SSSV lock & landing nipple number, irretrievability of SSSV tubing, wiring and equipment, serial number, working pressure, service class and redress history records, nature of failure, observed conditions which could have caused failure, probable and secondary cause of failure, failure consequence data should also be included.
- *Previous repair data*: If any. This should include: Identification Information: operator name, date of occurrence, field/area, lease name/platform/well number, equipment identification part vendor, model, size, part number, serial number, data on operating pressure and control fluid, actual installed water depth, part size/pressure rating, corrective action taken during repairs to prevent recurrence, name of persons performing repairs: Name, title, company, signature and date. Replaced components list: part number and serial number of replaced parts, number of parts replaced, description, part number and serial number of new parts, manufacturer of new parts.
- *Test results*: If the test was furnished by the operator or conducted by the manufacturer, failure mode, leakage rate, control fluid, and operational data (opening and closing pressures).
- *Causality and Consequence data*: This field should contain data fields for any deaths or injuries regardless of how severe and should specify the causes of death or type of injury (e.g., whether burn, blunt force trauma, pressure overload, etc.). In addition, information regarding environmental damage (e.g., petrochemical leakage or other environmental impacts) as well as property damage, business disruption costs or other associated monetary losses should be included. Causality information should be given to integers (e.g., 1, 2, 3, etc.) and environmental costs should note the amount and type of commodity released into the environment (e.g., number of barrels). Damage and property costs should be in non-inflation adjusted U.S. dollars to facilitate consequence comparisons.

Data Analysis Requirements for Failure Reporting Systems

BSEE is likely concerned with at least five different types of analysis queries. These should help BSEE determine the types of end-user tools required to analyze and report on the data and should support BSEE's regulatory mission.

1. Simple descriptive queries: These are the simplest queries. They involve simple counting, summing and averaging. A sample verification query might be, "How many failures occurred in a given month in the Gulf of Mexico?" or "What is the mean number of failures in all petrochemical companies in the Gulf of Mexico?" This information could be very important for baseline reporting and accordingly for BSEE regulatory evaluation studies.
2. Analysis of Change Queries: These queries involve manipulating the data to provide measures of business performance. A sample analysis of change query is "What is the percent change in the number of failures in the past three years?" or "Which oil well operators had the largest failure reduction in the past three years?" This kind of analysis can be important in determining the effectiveness of new regulations.

3. Basic Exception Reporting: These queries involve creating lists based on attributes or behaviors. A sample exception report query is “What are the top 10 companies with the most failures?” Reports can be useful in allowing BSEE to assign enforcement or inspection staff resources.
4. Intensive Reporting: These queries include complex metrics and reports and can supplement existing BSEE reports. For example, BSEE produces an accident report for major significant events in their area of jurisdiction. Intensive reporting in the form of perhaps a “major critical incidents” annual report with data tables could supplement existing BSEE reporting and may be useful in meeting legislative oversight or “sunshine” requirements.
5. Correlative or Causal Analysis: These are complex queries that try to associate or predict events. These queries are harder to answer using standard structured query language statements and often require specialized statistical operations. This type of analysis can answer questions like, “Can improper previous repair cause different failure types to occur?” or “Are different operators associated with different types of failure?” This type of analysis will be helpful in determining whether the action on new regulations is required.

Data Formatting Requirements for Failure Reporting Systems

The formatting of the data will play an important role as well. In this regard there are two key elements of formatting:

Plain English Requirement

Given information asymmetries, industry may claim that their highly technical and complex systems require a high level of industry participation in setting a regulatory agenda (Reidel, 2014). The complexity of these systems may produce language dense with engineering terms.

The technical language makes information exchange a difficulty within the industry, as well as between the industry and regulator. In order to address this, ABS Consulting recommends any industry data collected for regulatory purposes should have a plain English requirement. All technical terminology and data fields should be described using wording in data fields that are easily understandable to a layman.

Standardized Machine Readable Formats

Any data collected for regulatory analysis needs to be capable of being easily machine readable and more importantly easily convertible into universally standard data types such as comma delimited text files, Microsoft Excel spreadsheets, or similar files. Furthermore, all types of data should be easily recognizable and in standard data types such as integers or strings such that they are easily enterable in a diversity of databases or data warehouses. Easy machine readability should ensure that data is robust to changes in computing technology or BSEE organizational evolutions.

5.7 Liabilities

Industry SMEs voiced concerns regarding the issue of liability. For non-critical health, safety or business operations issues, SMEs felt that disclosure of a failure incident could subject the reporting company to legal or regulatory action, potentially undermining reporting rates (Anonymous, 2015).

Failure reporting can pose complex liability issues. For USCG's CASREP, the monitoring and enforcement regulations that apply to the prevention of human injury and death or environmental harm carry with them higher levels of public scrutiny. As a result, USCG's failure reporting system is prescriptive in nature and reflects these smaller margins for error.

Failure reporting can make some shifts in the burden of liability in certain situations. For example, if an oil drilling operator experiences a minor oil spill but is lower than the regulated reportable limit, a concerned party (such as Greenpeace, local government, international government, environmental organization, etc.) could decide to pursue litigation against the company. Some liability could fall partly or fully upon the regulatory body (BSEE, IADC, etc.) for not having a stringent reporting requirement.

If there is a failure reporting requirement that is less than an enforceable requirement, the oil company could report the information on spills, which a concerned party could litigate due to environmental or other damages from the spill. The concerned party may not have known about the spill if it were not for the failure reporting requirement, then liability of the data management and proprietary information would shift to the regulatory body.

Lastly, in this example, if the minor oil spill is a finable offense according to the regulator's reporting requirements and the operator chooses not to report the failure incident, then the liability would shift heavily upon the company.

Industry standards do provide companies discretion on what is reported and how to best apply a failure reporting system. This shows the company going above the minimum requirements and showing a good-faith effort to develop enhanced safety company policies.

However, since API proposes standards but does not implement these standards, the company is required to implement a system that fits their operations, resulting in non-standard application of the standard across the industry.

Other domestic agencies (Environmental Protection Agency [EPA], PHMSA, and NRC) have created insurance pools to reduce the financial impact in case of an incident. Typically, these insurance pools are created by an act of Congress. A negative impact of insurance pools is that they can depress over-compliance, particularly of low-cost vendors who believe the insurance pool could cover the financial liability of an incident.

Agencies like USCG and DOT PHMSA have the responsibility for quality control and data management. In a failure reporting system, the data collected will need to be aggregated and analyzed to effectively increase the utility of data collection. Privacy and proprietary information issues become a liability for BSEE, if it collects the data.

5.8 Application to BSEE

None of the models reviewed for this study should be considered a "perfect fit" to meet BSEE's goals. Many of the models focus solely on work-related injuries and have no provisions for capturing failure reports for incidents involving equipment or structures. Even within those models that focus on work-related injuries, there is no consistency in the definition of what constitutes a work-related injury, with one of the models only captures fatalities. Others models strictly capture incidents involving equipment or structures but do not include work-related injuries. Only a few of the models address risk management or corrective actions.

The IADC's ISP is a good model but is very limited in scope. The IADC participating companies only report work-related recordable injury or illness incidents. The ISP does not encompass structural or equipment failures.

The UK HSE's RIDDOR model, like the IADC's ISP, is limited to incidents which cause physical injury. Also, like IADC's model, RIDDOR does not encompass structural or equipment failures. However, unlike IADC's model, which is voluntary, RIDDOR is mandatory.

Despite many commonalities between BSEE and the USCG, the USCG failure reporting model does not represent a good opportunity for imitation. The USCG's failure reporting system, as codified in 46 CFR 4, does capture work-related recordable injuries and it requires reporting of structural or equipment failures. But the USCG model is only reactive regarding incidents and there is no corrective action component. Additionally there is a gap in 46 CFR Part 4, which does not directly link the failure of USCG approved equipment (critical equipment) to a requirement to report a failure of such equipment unless a marine casualty incident occurs.

NRC's model is comprehensive, and data concentrated. The NRC model also includes requirements for corrective action elements. Unfortunately, it is complex and labor intensive. There are multiple failure reporting paths and requirements within the model that are specific to failure types, all requiring extensive documentation.

The PHMSA failure reporting model provides a suitable outline of reporting requirements, but it is PHMSA's methodologies for collecting and analyzing data from its failure reporting system that is of greatest interest. PHMSA's mandatory internet based failure reporting submission portal presents an exciting approach to automating and standardizing data collection. PHMSA's approach enhances accountability, timeliness, data reliability and uniformity.

Of the domestic models for failure reporting reviewed for this study, the DoD FRACAS is the most comprehensive failure reporting system. It embodies many of the best practices identified in previous discussions, including a corrective action component. Additionally, there are many off-the-shelf software applications for the model. However, it is resource intensive and could be perceived as overly bureaucratic.

The Norway PSA model mandates failure reporting that captures work-related recordable injuries, and it requires reporting of structural or equipment failures. The PSA model has risk reporting requirements that provide qualitative and quantitative indicators. And the PSA maintains extensive databases to capture and analyze failure reports. A potential next step is to do a detailed analysis of the PSA model to determine if it may be readily adapted to BSEE's requirements.

6. Recommendations

Successful programs set the standard for what must be reported and what is a reportable incident. Failure reporting should be incorporated into an organization's LCM system. In a properly working failure reporting system or LCM system, unscheduled maintenance and failures may trigger a failure report, depending on what threshold is set.

ABS Consulting identified several Best Practices for failure reporting systems. Two key practices are having a clear and understood standard of what is reportable and having a mechanism for reporting once the threshold is hit. Some agencies have created an automated reporting mechanism for their industry. Successful programs provide for common reporting systems.

A key question that kept arising was if BSEE does create a failure reporting system, what is BSEE going to do with the data they collect? Other agencies, like the USCG, have faced and currently face criticism about the data collected, but the USCG does not have a strong mechanism to create or manage a safety system.

If BSEE does provide a structure for data collection for a failure reporting system, BSEE would need to have a clear and documented process about what the data collected are, what they will be used for, and how all the data are going to be used as actionable items in the future.

If BSEE collects this data, what is the responsibility of BSEE with the data? Will the responsibility be to solely collect the data? Will it be to collect and then analyze the data? Or will it be to collect and analyze the data in order to provide risk assessments to industry, feedback to OEMs, and perhaps pose corrective actions via regulation?

Another key question would be, how will this information differ than what is collected by BSEE that is separate or distinct from data collected by OREDA?

Increased data reporting and data analysis through increased cooperation could provide benefits of seeing common issues across the industry. Some industry members acknowledge the need for failure reporting; however, there is a lot of mistrust of each other and of the regulator in the U.S. O&G industry. Companies are wary of providing data if there might be a penalty, liability, or legal action from reporting. Current data published, like the safety statistics, do provide some information, but there is still a clear need for failure reporting.

If failure reporting were required and had retaliatory issues resolved, many of the larger companies may look forward to the collection of the data and learn from each other, since the companies would have an interest to not repeat other's mistakes.

The retaliatory issue is also present with the use of subcontractors. Currently, subcontractors feel if they report something, then the prime might switch contractors. In a voluntary system, the subcontractors would still be in this similar position; however, if there is a requirement for reporting, then a subcontractor would have incentive to comply.

Currently, individual companies make an internal decision then decide to push the information out to the OEM. Even at this point, an OEM might disagree with the assessment and not take action. An example provided was of the issues associated with Crosby shackles. With the introduction of knock-off parts, these shackles were breaking at a much higher rate. For an individual company, they might not know if the part was an original or a fake, thus would make an internal decision, then potentially report to the OEM. The OEM that is receiving the reports may recognize their part is not at issue, but the knockoff parts were, thus may not take action. If a failure reporting requirement were implemented, this may have been noticed throughout the industry as a widespread issue instead of an isolated case.

No matter the approach, clear definitions should be a requirement. BSEE should provide an overlay of definitions of the minimum requirements for compliance, provide an auditing requirement, and provide specific data hooks for relevant data.

6.1 Recommendation 1: A Balanced Approach

The following recommendations are based on information collected during the research of the above organizations. Developing a regulatory framework that meets the needs of the government yet provides enough flexibility to accept industry input and still meets the regulatory enforcement requirements in an ongoing policy challenge. Any regulatory regime adopted by BSEE needs to be robust enough to keep industry practices, employees and the environment safe, yet flexible enough to not create an excessive resource burden on industry and adaptable enough to respond to changing technological and social conditions.

Our research suggests industry will want the opportunity to have input based on business case situations and lessons learned to help mold any new regulations into those that are realistic and feasible. Industry will also require an effective feedback mechanism that will provide for real time or nearly real time results based on data input and potential changes that could result from the data requested. This will provide for a synergistic partnership between industry and BSEE and the result will be effective, useful and functional regulations and requirements that meet the needs for all parties concerned.

ISO and API standards are already in use, thus no matter the direction of how to best address the implementation of a failure reporting system, incorporation of industry standards will be a clear starting point. BSEE’s approach to incorporating API Standard Q2 and Q3 will provide a basis and starting point for development of a system, and with additional regulatory baselines, the industry can develop their programs with the bare minimum covered and with a standardized list of components or systems, as will be outlined in Task 4.

6.2 Recommendation 2: Suggestions for Formulating an Effective Failure Reporting System

The task of formulating an effective failure reporting system may be a challenging one. Accordingly, six suggestions are offered here to help BSEE address the task of regulating failure reporting in a diverse and changing offshore industry.

1. *There are mature and robust failure reporting systems utilized by other Domestic Federal Agencies such that BSEE should have adequate models on which to base failure reporting policy.* USCG's MISLE database and CASREP system should be closely studied, as the regulatory and procedural 'building blocks' of the USCG's Failure Reporting system have been well defined, exist within the same regulatory sphere as BSEE and have withstood the test of time.
2. *Involvement by industry is an important element of successful failure reporting programs.* Following BSEE's decision to incorporate API's Standard Q1 and Q2, this review suggests that industry participation is an important element of failure reporting success. ABS Consulting's research and interviews have highlighted the role of industry underreporting[18] in limiting the effectiveness of existing failure reporting systems. In addition, the recent controversy surrounding PHMSA's regulation of the DOT class 111 rail cars indicates that regulator response to failure trends can be ineffective without active support from industry. Finally, as shown by the continual updates to the API and ISO standards, industry input helps to ensure that failure reporting information is adequate and properly updated to meet the goals of the failure reporting system program.
3. *Failure reporting must be easy for industry and there should not be punitive consequences for reporting failures.* One consistent theme through ABS Consulting's SME interview is that non-critical failures suffer from underreporting by smaller industry actors. Accordingly, BSEE should endeavor to ensure failure reporting communications (paperwork, data uploads, telephone notifications) are easy and quick to submit. In this regard, a review of PHMSA's web-based reporting mechanisms may be instructive. BSEE should also endeavor to ensure failure reporting does not have punitive consequences for industry participants who submit reports. In this regard a review of the UK Oil and Gas' Industry Mutual Hold Harmless (IMHH) agreement may be useful to help to craft a regulatory or legal structure which places limits on industry participant liability.
4. *Effective failure reporting takes time and cannot be achieved without sustained organizational commitment.* Many of the failure reporting programs in this review have taken time to achieve their intended results. While the USCG program has recently shown strong results in reducing the number of substandard vessels in U.S. waters, the USCG program has been over 30 years in the making. PHMSA' failure reporting data has shown a consistent decline in pipeline related accidents; however, the results from PHMSA's program are often the result of multi-year efforts. Finally, our review of the NRC and

[18] This is especially a problem for non-critical events, near-misses or similar occurrences.

USCG's failure reporting system suggest that often regulatory agencies cut funding for data dissemination and analysis, thus limiting the utility of these systems. Accordingly, ABS Consulting recommends that BSEE carve out long term funding adequate to maintain the information technology, analysis and dissemination backbones of any proposed failure reporting system.

5. *Failure reporting systems need independent scientific evaluations*. High quality scientific evaluations of failure reporting systems are needed for three reasons. First, few of the failure reporting systems reviewed here, whether maintained by Federal regulatory agencies, international regulators or industry, had robust scientific effectiveness evaluations conducted by neutral third parties. Second, failure reporting systems offered by industry are often based on consensus and can therefore omit program elements or scope considerations which are objectively important, but are not viewed as important by industry. Third, as shown by the Deepwater Horizon disaster and numerous fatal accidents since then, effective failure reporting in the offshore O&G industry can be a matter of life and death. Accordingly, high quality data with strong scientific methodology should be utilized to review important cause and effect questions, such as: does a history of near-misses predict fatal accidents? Current systems are primarily reactive and are therefore limited in this regard.
6. *Failure reporting should use finely graded measures of success*. Many of the Domestic Federal Agencies reviewed here, as well as some of the International Regulators, report failures along a graded approach (likely to fail on a 1 to 10 scale), rather than simply a binary metric (failure, yes or no). The advantage of this is primary for BSEE data monitoring and analysis purposes. It is easier to rank order companies, equipment or failure types based on graded information than based on binary information.

7. Conclusions

Our review points to the key theme of integration and indicates that successful programs are clear and unambiguous in both their mandates and seek input from both the industry and regulatory communities. They are also typically incorporated into organizational or agency's LCM system.

ABS Consulting identified several Best Practices for failure reporting systems. Four key practices are: 1) having a clear and understood standard of what is reportable, 2) a mechanism for reporting once the threshold is hit, 3) a sustained organizational commitment to funding, and 4) effective industry outreach.

On a final note, we conclude that future questions facing BSEE are likely to involve data concerns by industry: if BSEE does create a failure reporting system, what is BSEE going to do with the data they collect? Other agencies, like the USCG, have faced and currently face criticism about the data collected. How will data safety be ensured? How will data be shared? Will the data be used to impose new regulations on industry?

To prevent the next major disaster that may have ramifications for BSEE, a prescriptive approach may reduce liability for specific systems and components; however, does not address systems or equipment not already categorized. Ultimately, BSEE will need to identify what the critical components are, and whether they are being maintained. How BSEE goes about defining critical components, and at what level of analysis is optimal will be addressed in the following Task 4 report.

After decades, the USCG's inspection requirements and critical equipment has matured to capture materials and equipment that lead to issues, instead of the end cause of an incident, by conducting risk-based decision-making tools like Failure Mode, Effects, and Criticality Analysis, bowtie analysis, risk identification, or other approaches to identify what needs to work in the event of an emergency.

Taking a risk-based approach to critical equipment would aid in determining where the highest levels of criticality reside and what data is required to make a responsive and applicable decision. By conducting a risk-based approach, this would provide BSEE the information on what data to collect on control systems.

Conducting a risk assessment of hazards and failure modes can result in changes beyond an LCM or failure reporting system, to impacting other regulatory areas like implementing design requirements.

A risk-based approach would require that the data collected would provide the quantification of frequency and consequence of an equipment failure. From these values, aggregated to the system level, a risk score can be develop to identify what the high risk, high consequence systems are. This risk score would then impact what data are collected and how inspections may be conducted.

A critical issue is what BSEE will do with the data? BSEE would need to aggregate, sanitize, and analyze the data. To ensure expedient processing, having specific data elements that are uniform would reduce time of analysis and dissemination.

A key issue raised by industry is turnover of the data back to industry. If the industry is providing this data, those interviewed stated that they would want to see the benefit in the form of usable data. In previous data collection and dissemination, the data were scrubbed to remove proprietary or identifying information; however, this resulted in data that had little usable information for industry.

A recommendation is that BSEE start with a pilot program with the top 10 or 15 critical components of interest then grow the list over time. Given that a data request would require rulemaking, a short list of high risk and high consequence may be more palpable to the industry than an exhaustive list like USCG currently has. Having a short and specific list, this reduces the risk of collecting data on lower risk and lower consequences, but with high frequency like kitchen fires. While such events may be common and can lead to catastrophe, the industry may be resistant, therefore focusing on the clear and accepted critical systems.

There are certain systems that required a more prescriptive approach beyond current industry standard requirements. High risk and high consequence systems (e.g., BOP, cranes, electrical systems, etc.) should have increased monitoring and inspections. These critical systems need to be mandated to be prescriptively checked. Even in a Safety Case approach, to prevent future events, there still needs to be minimum requirements. If BSEE sees that 20 of these systems are failing, then this might become a critical item for future inspection.

If BSEE does provide a structure for data collection with either an LCM or a failure reporting system, BSEE would need to have a clear and documented process about what the data collected are, what they will be used for, and how all the data are going to be used as actionable items in the future. And perhaps most importantly, can BSEE's failure reporting data adequately address the organizations ultimate goals, promoting and protecting health and safety offshore.

Appendix A – Task 2 and 3 Agency Template

Introduction

PROGRAM HISTORY

How long has the program(s) been in place?

PROGRAM INFORMATION, POLICIES AND PROCEDURES

Task 2, 2.3.4.2 - What type of policies, programs or guidelines are in place in regards to a LCM program from industry, trade groups or trade associations?

Task 3, 2.3.5.1 - Are failures reporting systems utilized by regulatory bodies? If so, which regulators use them? What types of systems? How long have they been utilized?

Task 3, 2.3.5.7 - Identify any commercial, for profit Failure Reporting systems that are available on the open market and to which industries they are associated with. Evaluate such systems and report on their cost to participate and their historical performance.

PROGRAM ELEMENTS, BEST PRACTICES AND LESSONS LEARNED

Task 2, 2.3.4.3 - What components do the various LCM programs evaluated under this contract contain? Not contain

Task 2, 2.3.4.5 - Do any of the groups evaluated under this contract make use of industry standards, recommended practices, specifications, etc. which address the contents of a LCM program? If appropriate, identify the document being used.

Task 3, 2.3.5.4 - Has the data generated from a Failure Reporting system ever been used by an equipment manufacturer to redesign or change equipment specifications? Provide a detailed accounting of how this process has worked for any identified occurrence.

THE ROLE OF INDUSTRY

Task 3, 2.3.5.2 - Are failures reporting systems utilized by individual companies, industry trade groups or associations? If so, which companies or industry trade groups or associations use them? How long have they been utilized?

STATUTORY OR REGULATORY ELEMENTS

Task 2, 2.3.4.1 - What type of regulations, policies, or guidelines is in place in regards to a LCM program by the regulatory community?

PROGRAM EFFECTIVENESS

How do regulators assess the effectiveness of their program(s)?

Task 2, 2.3.4.4 - How effective are the various LCM programs? How is effectiveness/performance of these programs measured? How long have these programs been in existence?

Task 3, 2.3.5.3 - How effective are the Failure Reporting systems in use? How is effectiveness/performance of these programs measured?

Task 3, 2.3.5.5 - How are Failure Reporting systems structured in regards to use of proprietary data/trade secrets in regards to equipment covered under a system, company anonymity when participating in such a system (is anonymous reporting effective and how is it achieved? If anonymous reporting is not used can such a system still be effective?) and how is data from the system distributed and utilized by a company or a regulator to mitigate risk.

Task 3, 2.3.5.6 - Are safety/environmental incidents included in a Failure Reporting system or just equipment malfunctions/upsets? If not, are they reported separately? If they are part of the Failure Reporting system include in assessment of them.

Task 3, 2.3.5.8 - Define the associated data analysis requirements required in a Failure Reporting system and specify what data needs to be collected for regulatory purposes.

PROGRAM OUTCOMES

How do regulators evaluate outcomes and satisfaction with their program(s)?

Task 3, 2.3.5.9 - Develop chart flow diagrams of failure reports from origin back to OEM, service providers, and the regulatory body for any systems evaluated.

EFFECTIVENESS DATA

Task 3, 2.3.5.10 - Identify examples of OEM and service provider utilization of such failure reports in product assessment and improvement and report on how well it has worked.

Provide available data on the program's effectiveness based on the prevalence or avoidance of various consequences.

LIABILITIES

Determine the effect, if any, of each program example on the legal liabilities of the government regulatory and the members of the regulated industry.

POTENTIAL APPLICATION TO BSEE

Describe how this program may be applicable for BSEE use?

Appendix B – NRC LER 2011-005

Entergy

Entergy Nuclear Operations, Inc.
Palisades Nuclear Plant
27780 Blue Star Memorial Highway
Covert, MI 49043
Tel 269 764 2000

Anthony J Vitale
Site Vice President

PNP 2011-066

October 03, 2011

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

SUBJECT:	Licensee Event Report 2011-005, Service Water Pump Shaft Coupling Failure Palisades Nuclear Plant Docket 50-255 License No. DPR-20
REFERENCES:	10 CFR 50.73, 10 CFR 21.21

Dear Sir or Madam:

Licensee Event Report (LER) 2011-005 is enclosed. This LER is being submitted in accordance with 10 CFR 50.73(a)(2)(i)(B) as a condition prohibited by the plant's Technical Specifications and 10 CFR 21.21(c) for reporting defects, and failures to comply, associated with substantial safety hazards for dedicated items.

This letter contains no new commitments and no revisions to existing commitments.

Sincerely,

AJV/tad

Enclosure: Licensee Event Report 2011-005

CC Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

NRC FORM 366
U.S. NUCLEAR REGULATORY COMMISSION
(10-2010)

APPROVED BY OMB NO. 3150-0104 EXPIRES 10/31/2013

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

1. FACILITY NAME	2. DOCKET NUMBER	3. PAGE
PALISADES NUCLEAR PLANT	05000255	1 of 4

4. TITLE: Service Water Pump Shaft Coupling Failure

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
08	09	2011	2011 -	005 -	00	10	03	2011	FACILITY NAME	DOCKET NUMBER

9. OPERATING MODE: 1

10. POWER LEVEL: 100

11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check all that apply)

☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.73(a)(2)(i)(C)	☐ 50.73(a)(2)(vii)
☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☐ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)
☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)
☐ 20.2203(a)(2)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)
☐ 20.2203(a)(2)(ii)	☐ 50.36(c)(1)(ii)(A)	☐ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)
☐ 20.2203(a)(2)(iii)	☐ 50.36(c)(2)	☐ 50.73(a)(2)(v)(A)	☐ 73.71(a)(4)
☐ 20.2203(a)(2)(iv)	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(B)	☐ 73.71(a)(5)
☐ 20.2203(a)(2)(v)	☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(C)	☒ OTHER Specify in Abstract below or in NRC Form 366A
☐ 20.2203(a)(2)(vi)	☒ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(v)(D)	

12. LICENSEE CONTACT FOR THIS LER

FACILITY NAME	TELEPHONE NUMBER (Include Area Code)
Terry Davis	(269) 764-2117

13. COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX
B	BI	CPLG	H331	Y					

14. SUPPLEMENTAL REPORT EXPECTED		15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
☐ YES (If yes, complete 15. EXPECTED SUBMISSION DATE)	☒ NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines

On August 9, 2011, at 1202 hours, service water system (SWS) pump, P-7C, failed to deliver discharge pressure. As a result, a 72-hour limiting condition for operation (LCO) was entered in accordance with Technical Specification (TS) 3.7.8 condition A, due to one or more SWS trains being inoperable. The TS 72-hour LCO was exited after approximately 63 hours on August 12, 2011, at 0309 hours when repairs and testing on P-7C had been completed.

Investigation into the failure revealed a broken pump shaft coupling. The failure mechanism of the coupling was determined to be intergranular stress corrosion cracking (IGSCC). A past operability evaluation concluded that, based on the failure mechanism of the coupling, P-7C would have been unable to operate satisfactorily for the required 30-day mission time. Therefore, P-7C was inoperable from July 10, 2011, until the coupling failed on August 9, 2011. During the period P-7C was considered inoperable, SWS pumps P-7B and P-7A were removed from service, on separate occasions for brief periods of times, for the performance of routine maintenance activities. The requirement of TS 3.7.8 condition C, that 100% of the required post accident SWS cooling capability be available, was met at all times during the 30-day period when P-7C was considered inoperable.

The cause of the IGSCC was due to inadequate coupling design specifications. P-7A and P-7B shaft couplings were replaced using newly designed couplings. Replacement of the shaft couplings on P-7C, with the new design, is scheduled. This event is reportable in accordance with 10 CFR 50.73(a)(2)(i)(B) as a condition prohibited by TS and 10 CFR 21.21(c) for reporting defects, and failures to comply, associated with substantial safety hazards for dedicated items.

NRC FORM 366 (10-2010)

1. FACILITY NAME	2. DOCKET	6. LER NUMBER			3. PAGE
		YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	
PALISADES NUCLEAR PLANT	05000255	2011	- 005 -	00	2 OF 4

PLANT CONDITIONS

On August 9, 2011, at the time service water system (SWS) [BI] pump [P], P-7C, failed, the plant was in Mode 1, operating at approximately 100% power.

INTRODUCTION

The SWS provides a heat sink for the removal of process and operating heat from safety-related components during a design basis accident or transient. During normal operation or a normal shutdown, the SWS also provides this function for various safety-related and non-safety-related components. During post-accident conditions, with all other SWS and related system components operable, 100% of the required SWS post-accident cooling capability can be provided by any one SWS pump.

The SWS consists of three pumps, P-7A/B/C connected in parallel, taking suction from a common intake structure supplied by Lake Michigan. The discharge of the pumps flow into a common header before splitting into three headers (two critical headers for safety-related equipment and a single non-critical header for non safety-related equipment). The return piping from the three headers join into a common line and discharge to the cooling tower makeup basin.

The three SWS pumps are comprised of a two stage pump end with stainless steel (SS) impellers. The pump end is coupled to the motor through six line shafts, a packing shaft, and a motor shaft connected by eight couplings all of the same design.

The design specification of the line shaft couplings for the three SWS pumps was changed in December 2007. The design specification included information from previous engineering evaluations that changed coupling material from carbon steel to 416SS. The line shaft couplings for P-7A were replaced in April 2009. The line shaft couplings on P-7B were replaced in May 2010. The line shaft couplings for P-7C were replaced in June 2009.

On September 29, 2009, P-7C failed to deliver discharge pressure. The investigation into the failure revealed a broken coupling between the top line shaft and the packing shaft. An analysis determined that the coupling failed from intergranular stress corrosion cracking (IGSCC). There are three parameters that must be present for couplings to fail by the mechanism of IGSCC; susceptibility of material for IGSCC, a corrosive environment, and a stress intensity that exceeds the threshold for IGSCC on the pump shaft coupling. Inherent to the Palisades design is the corrosive environment (lake water) and the stress applied during pump operation. The failed coupling was determined to have been improperly heat treated, based on the high hardness value of the 416SS coupling, rendering it susceptible to IGSCC. Improper heat treatment was a result of issues within the quality control program of the vendor, HydroAire Services Inc.

EVENT DESCRIPTION

On August 9, 2011, at 1202 hours, P-7C, failed to deliver discharge pressure. A 72-hour limiting condition for operation (LCO) was entered in accordance with Technical Specification (TS) 3.7.8 condition A, due to one or more SWS trains being inoperable. Work to restore P-7C began immediately. During disassembly, it was determined that the line shaft coupling [CPLG] failed similarly to the failed coupling in the same pump in September, 2009.

LICENSEE EVENT REPORT (LER)
CONTINUATION SHEET

1. FACILITY NAME	2. DOCKET	6. LER NUMBER			3. PAGE
		YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	
PALISADES NUCLEAR PLANT	05000255	2011	- 005	- 00	4 OF 4

CORRECTIVE ACTIONS TO BE TAKEN

Replacement of the 416SS shaft couplings that remain on P-7C with the 17-4PH SS design couplings.

Creation of an Engineering Standard that clearly identifies station requirements and expectations for material changes affecting installed plant equipment.

ASSESSMENT OF SAFETY CONSEQUENCES

No actual safety consequences resulted from this event. Operating service water pumps continued to meet all critical, non-critical and containment service water system cooling loads. Potential safety consequences of this event are of low safety significance: the equipment necessary to safely shutdown the reactor and maintain safe shutdown conditions under normal and emergency circumstances remained intact and available.

PREVIOUS SIMILAR EVENTS

LER 2010-001, Service Water Pump Shaft Coupling Failure.

Appendix C – IADC Safety Alert 09 – 13

Safety Alert

From the International Association of Drilling Contractors

ALERT 09 – 13

DROPPED DRAWWORKS PLATFORM

WHAT HAPPENED:

During the process of lowering the draw-works and support structure to the ground, one of two 35 ton sheaves used in the pulley system failed, causing one side of the draw works structure to fall 3 to 4 meters (10 to 13 feet) to the rig sub base. When the structure collapsed, five employees fell, resulting in major injuries (fractured bones and dislocated shoulder) and first aid cases. Potential was for multiple fatalities. The incident also caused major damage to the substructure and draw-works resulting in the rig being unserviceable. A second shackle had been added to the pulley system sheave used to lower the draw-works. This additional shackle caused misalignment of the sheave with the direction of the load. While lowering the platform, the tension in the pulley system increased forcing the sheave plates apart, releasing the sheave pin and resulting in immediate release of the cable and draw-works.

WHAT CAUSED IT:

- Personnel were in exposed position during lowering of the draw-works.
- The person in charge had not performed the operation before and procedures did not give detailed and clear guidelines for the rig down operation.
- Although experienced personnel were present they were not listened to and an extra sheave was added to the rigging system.
- There was a failure in the Management of Change (MOC) by altering an existing approved design and the lack of documentation of the rig down procedure to assure consistent performance.
- Person-in-charge handover did not address safety critical tasks.
- Lifting equipment inspection and control procedures were not followed.

The Corrective Actions stated in this alert are one company's attempts to address the incident, and do not necessarily reflect the position of IADC or the IADC HSE Committee.

Safety Alert

From the International Association of Drilling Contractors

CORRECTIVE ACTIONS: To address this incident, this company did the following:

- The rig has been through extensive repair, redesign and recertification by the manufacturer.
- All design issues and the rig documentation were revised by the manufacturer.
- Updated rig move procedures to include details of critical safety tasks.
- Developed lift plans and consider Permit To Work requirements for significant lifts.
- Identified high risk areas during lifting and load movements and removed personnel from these areas during the lifting/loading operation.
- Confirm lifting equipment is certified and that personnel are competent to perform their tasks.

Appendix D – IADC Safety Alert 14 – 01

Safety Alert

From the International Association of Drilling Contractors

ALERT 14 - 01

INTERNAL EXPLOSION RUPTURES CROWN MOUNTED COMPENSATOR PIPING

WHAT HAPPENED:

Two employees were in the derrick equalizing the internal pressure between Composite Air Pressure Vessels (CAPV) on the Crown Mounted Compensator (CMC) when an ignition occurred inside the system. Either heat generated by adiabatic compression or static generated by the air transfer led to ignition inside the CAPV. Thereafter, the associated raise in pressure and temperature resulted in the interconnecting piping rupturing. Two employees received non-life threatening injuries and were subsequently transported to a shore-based medical facility for further treatment.

Failed CAPV and Interconnected Pipe

CAPV Outlet Flange

Ruptured Interconnected Pipe

Ruptured Interconnected Pipe

WHAT CAUSED IT:

- Combustion occurs because of a combination of three elements: heat, fuel, oxidizing agent (e.g. oxygen).
- High temperature is a result of rapid pressure increase in a pressurized air system. The CAPV Bottle that was being brought on-line was at a much lower pressure than the operating system pressure.
- A fuel source in the CAPV Bottle ignited due to the high temperature generated by the air transfer or static that was caused by the rapid air transfer.
- The temperature rise generated by the air transfer exceeded the melting temperature of the CAPV liner.

CORRECTIVE ACTIONS: To address this incident, this company did the following:

- The company notified the manufacturer of the event to assist in the investigation.
- The company held safety stand-downs to review the incident and discuss the lessons learned.
- The company developed specific work instructions to bring CAPV online in accordance with manufacturer's recommendations which included following a cool down cycle while filling CAPV bottles with air.

The Corrective Actions stated in this alert are one company's attempts to address the incident, and do not necessarily reflect the position of IADC or the IADC HSE Committee.

Appendix E – IADC Five Year Summary Report

IADC ISP PROGRAM

5 Year Summary Report
Lost Time And Total Recordable Incidence/Frequency Rate

CATEGORIES	TYPE	2013 INCD Rate	2013 FREQ Rate	2012 INCD Rate	2012 FREQ Rate	2011 INCD Rate	2011 FREQ Rate	2010 INCD Rate	2010 FREQ Rate	2009 INCD Rate	2009 FREQ Rate
US Land	LTI:	0.51	2.54	0.51	2.55	0.87	4.34	1.02	5.12	0.95	4.73
	DART:	0.96	4.81	1.16	5.79	1.75	8.73	1.99	9.96	1.93	9.64
	RCRD:	1.58	7.92	1.97	9.87	3.09	15.43	3.44	17.19	3.11	15.54
US Water	LTI:	0.15	0.74	0.19	0.93	0.18	0.91	0.24	1.18	0.20	1.01
	DART:	0.45	2.24	0.44	2.21	0.39	1.93	0.57	2.86	0.44	2.21
	RCRD:	0.78	3.91	0.93	4.64	0.82	4.11	0.86	4.31	0.87	4.36
Canada Land	LTI:	0.61	3.05	0.69	3.44	1.16	5.78	0.36	1.78	0.27	1.33
	DART:	0.76	3.82	1.31	6.53	1.54	7.71	1.07	5.34	0.53	2.66
	RCRD:	1.98	9.92	2.68	13.41	3.57	17.83	2.4	12.02	0.8	3.99
Canada Water	LTI:	0.00	0.00	0.00	0.00	0.31	1.53	0.19	0.95	0.00	0.00
	DART:	0.24	1.20	0.56	2.78	0.3	1.53	0.76	3.79	0.54	2.71
	RCRD:	0.24	1.20	1.39	6.95	0.61	3.06	1.14	5.69	0.81	4.06
Central America & Caribbean Land	LTI:	0.27	1.37	0.29	1.45	0.44	2.19	0.48	2.41	For Central & South America data prior to 2010 contact IADC	
	DART:	0.46	2.28	0.45	2.25	1.15	5.74	0.67	3.35		
	RCRD:	0.64	3.20	0.51	2.57	1.42	7.10	0.88	4.42		
Central America & Caribbean Water	LTI:	0.22	1.11	0.21	1.03	0.00	0.00	0.05	0.23	For Central & South America data prior to 2010 contact IADC	
	DART:	0.37	1.86	0.29	1.44	0.07	0.36	0.23	1.16		
	RCRD:	0.54	2.72	0.58	2.89	0.39	1.97	0.42	2.09		
South America Land	LTI:	0.16	0.79	0.17	0.84	0.18	0.52	0.23	1.13	For Central & South America data prior to 2010 contact IADC	
	DART:	0.37	1.84	0.33	1.67	0.52	2.61	0.61	3.05		
	RCRD:	0.51	2.54	0.42	2.11	0.75	3.77	0.94	4.69		
South America Water	LTI:	0.27	1.33	0.31	1.57	0.29	1.47	0.40	2.01	For Central & South America data prior to 2010 contact IADC	
	DART:	0.48	2.38	0.50	2.49	0.46	2.31	0.57	2.83		
	RCRD:	0.66	3.29	0.88	4.38	0.92	4.62	1.04	5.21		
European Land	LTI:	0.34	1.69	0.26	1.29	0.28	1.41	0.22	1.12	0.29	1.46
	DART:	0.39	1.94	0.31	1.55	0.31	1.56	0.27	1.35	0.36	1.80
	RCRD:	0.48	2.39	0.35	1.76	0.38	1.89	0.31	1.57	0.41	2.05
European Water	LTI:	0.27	1.34	0.27	1.37	0.31	1.55	0.22	1.11	0.33	1.64
	DART:	0.44	2.20	0.51	2.55	0.49	2.44	0.37	1.85	0.46	2.30
	RCRD:	0.85	4.24	0.82	4.11	0.80	3.99	0.73	3.66	0.71	3.55
Africa Land	LTI:	0.38	1.92	0.38	1.88	0.34	1.72	0.41	2.03	0.46	2.30
	DART:	0.86	4.32	0.50	2.50	0.49	2.47	0.56	2.82	0.78	3.91
	RCRD:	1.07	5.36	0.84	4.19	1.00	5.00	1.18	5.92	1.64	8.20
Africa Water	LTI:	0.16	0.81	0.19	0.95	0.28	1.39	0.27	1.37	0.23	1.13
	DART:	0.30	1.48	0.36	1.78	0.47	2.34	0.52	2.61	0.51	2.56
	RCRD:	0.52	2.61	0.55	2.73	0.81	4.07	0.96	4.80	0.83	4.16
Middle East Land	LTI:	0.14	0.72	0.17	0.86	0.22	1.12	0.18	0.89	0.24	1.21
	DART:	0.39	1.95	0.39	1.96	0.46	2.30	0.46	2.28	0.45	2.25
	RCRD:	0.65	3.23	0.73	3.65	0.83	4.16	0.86	4.31	0.89	4.46
Middle East Water	LTI:	0.08	0.39	0.06	0.31	0.12	0.60	0.23	1.15	0.15	0.73
	DART:	0.22	1.10	0.28	1.39	0.28	1.38	0.43	2.14	0.33	1.64
	RCRD:	0.29	1.47	0.46	2.28	0.53	2.67	0.78	3.89	0.68	3.40
Asia Pacific Land (Asia / Australia)	LTI:	0.22	1.08	0.21	1.05	0.31	1.56	0.20	1.00	0.27	1.34
	DART:	0.58	2.89	0.66	3.28	0.59	2.97	0.51	2.55	0.64	3.20
	RCRD:	0.94	4.70	1.06	5.32	1.02	5.08	0.93	4.67	1.03	5.16
Asia Pacific Water (Asia / Australia)	LTI:	0.15	0.76	0.18	0.89	0.14	0.69	0.17	0.87	0.30	1.52
	DART:	0.35	1.73	0.31	1.53	0.30	1.51	0.40	1.99	0.46	2.28
	RCRD:	0.54	2.72	0.47	2.33	0.63	3.17	0.75	3.76	0.85	4.25
INDUSTRY TOTALS	LTI:	0.26	1.29	0.26	1.31	0.36	1.79	0.39	1.95	0.37	1.88
	DART:	0.52	2.5756	0.53	2.6453	0.69	3.4537	0.76	3.809	0.71	3.568
	RCRD:	0.81	4.03	0.88	4.41	1.23	6.13	1.33	6.66	1.23	6.17

INCD = Incidence Rate (200,000 manhours) :	*LTI INCD Rate = (LTIs + FTLs) * 200000 / Total Manhours* *DART INCD Rate = (RWC + LTI + FTL) * 200000 / Total Manhours* *RCRD INCD Rate = (MTOs + RWCs + LTIs + FTLs) * 200000 / Total Manhours*
FREQ = Frequency Rate (1,000,000 manhours):	*LTI FREQ Rate = (LTIs + FTLs) * 1000000 / Total Manhours* *DART FREQ Rate = (RWC + LTI + FTL) * 1000000 / Total Manhours* *RCRD FREQ Rate = (MTOs + RWCs + LTIs + FTLs) * 1000000 / Total Manhours*

Appendix F – HPMS Program Activity Assessment

-------------------------- HPMS Program Activity Assessment --------------------

Activity	Poor 0 point	Fair 5 points	Good 10 points	Outstanding 20 points	Score (points)
GIS/LRS Adequacy	GIS/LRS is not maintained and/or does not reflect the entire Federal Aid System	GIS/LRS is maintained and does reflect the entire Federal Aid System. May not be integrated with the DOT Enterprise or completely up to date	GIS/LRS is maintained and does reflect the entire Federal Aid System. It is integrated with the DOT enterprise but may not be completely up to date.	GIS/LRS is maintained and does reflect the entire Federal Aid System. It is integrated with the DOT enterprise and is completely up to date.	
Data Submittal	Late with complete mileage and VMT data, other major data issues not explained	By June 15th , complete mileage & VMT data, major issues explained or data resubmittal	By June 15th , complete data and minor comments	By June 15th , no comments	
	Submittal letter brief and general comments	Submittal letter explains only recurring comments	Submittal letter explains recurring comments and edits	Submittal letter explains recurring comments, edits, and changes in procedures and processes	
SPR Work Program or State Planning Work Program	Decrease or inadequate funding or no priorities for data collection including staff, training or equipment	Adequate funding, some recognition of needs and new activities, but still no changes in staff, training, or equipment	Adequate or increased funding, more staff and training for selected activities	Adequate or increased funding for process review (or action plan) recommendations included in work program	
Quality Assurance	Minimal quality assurance, off-state system issues, many coding error messages	Basic quality assurance program for short term solutions including off-state system issues, some coding error messages explained in submittal letter	Quality assurance program implemented and coordinated with all data providers, minor isolated problems,	Quality assurance program documented, funded, and no major data coding problems found	
Traffic Data	Current year data provided with non statistical or non verifiable explanation for anomalies and unusual trends for F.C. or H.V. locations, Primary OHPI comments.	Current year data provided for all PAS, acceptable statistical justification for anomalies and unusual trends for F.C. or H.V. locations, Primary OHPI comments.	Current year data provided for all F.C., acceptable statistical justification for anomalies and unusual trends for F.C. or H.V. locations, Secondary OHPI comments.	Current year data provided for all F.C., no unusual trends by F.C. or H.V. locations, no OHPI comments.	
Pavement Data	Complete data provided on-state system updated on an infrequent cycle, off-state system data incomplete, Primary OHPI comments	Complete data provided on-state system updated on a 2 year cycle, plan developed for complete off-state system data, Primary OHPI comments	Complete data provided and collected with supporting explanations that differ from Field Manual, all current 1-2 year data, Secondary OHPI comments	Complete data provided and collected in accordance with Field Manual, all current 1-2 year data, no OHPI comments	
Sample Adequacy	Sample revisions needed, identified, but not made. Primary OHPI comments	Some sample revisions were made, sample adequacy assessed. Primary OHPI comments	Most sample revisions were made, sample adequacy assessed. Secondary OHPI comments	Sample revisions not needed or were made addressing all deficiencies and OHPI comments	
Total Score (140 max)					
Activity(s) Identified for Review: (Less than 10, more than one activity should be considered)					

State Date Year (Attach to your Status Report & Certification) Date of Assessment

References

AASHTOWare. (n.d.). *AASHTOWare Bridge Management Product Update*. Retrieved from http://aashtowarebridge.com/?p=376

Administration, U. D. (2011). *Distribution Integrity Management Program (DIMP) History.* Washington, DC: U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. Retrieved Feburary 5, 2015, from https://primis.phmsa.dot.gov/dimp/docs/History_of_DIMP_06152011.pdf

ALD. (2015, January 1). *ALD FRACAS Software*. Retrieved April 10, 2015, from http://aldservice.com/en/FRACAS/fracas-software.html: http://aldservice.com/en/FRACAS/fracas-software.html

American Association of State Highway Officials. (2005, January 1). *AASHTO - Programs* . Retrieved February 26, 2015, from http://www.transportation.org/Pages/Default.aspx: http://www.transportation.org/Pages/Programs.aspx

American Institute of Aeronautics and Astronautics. (2014, January 1). *About AIAA*. Retrieved September 30, 2014, from www.aiaa.org: http://www.aiaa.org/secondary.aspx?id=153

American National Standards Institute, American Petroleum Institute. (2007, December 1). *ANSI/API Spec Q1.* Retrieved September 26, 2014, from http://www.mambocert.com: http://www.mambocert.com/assets/downloads/20120523/20120523120312707.pdf

American Petroleum Institute. (2004, May 1). *API RP 75*, 3rd edition. Retrieved September 27, 2014, from www.techstreet.com: http://www.techstreet.com/products/1157045

American Petroleum Institute. (2006, April 1). *API RP 2FB*, 1st edition. Retrieved September 27, 2014, from www.techstreet.com: http://www.techstreet.com/products/1262245

American Petroleum Institute. (2007, May 1). *API RP 2D*, 6th edition. Retrieved September 28, 2014, from www.techstreet.com: http://www.techstreet.com/products/1503805

American Petroleum Institute. (2009, November). *API RP 574*. Retrieved January 2, 2015, from https://global.ihs.com/doc_detail.cfm?document_name=API%20RP%20574#abstract

American Petroleum Institute. (2011, December 00). *API Spec Q2*, 1st edition, Rev.1. Retrieved September 28, 2014, from global.ihs.com: https://global.ihs.com/doc_detail.cfm?&item_s_key=00579726&item_key_date=890631

American Petroleum Institute. (2011). *Specification for Quality Management System Requirements for Service Supply Organizations for thePetroleum and Natural Gas Industries.* American Petroleum Institute. Retrieved December 11, 2014

American Petroleum Institute. (2012, March 1). *API Spec 2C*, 7th edition. Retrieved September 28, 2014, from www.techstreet.com: http://www.techstreet.com/products/1830968

American Petroleum Institute. (2012). *Blowout Prevention Equipment Systems for Drilling Wells.* Washington, DC: American Petroleum Institute. Retrieved December 18, 2014

American Petroleum Institute. (2012). *Global Chemical Management | API Supporting SAICM.* Retrieved September 25, 2014, from API.org: http://www.api.org/environment-health-and-safety/health-safety/global-chemical-management/~/media/Files/EHS/Process-Safety/RASA-Brochure-ForWeb-HiRes.ashx

American Petroleum Institute. (2013, December 5). *API RP 571 Damage Mechanisms*. Retrieved January 2, 2015, from http://www.api.org/events-and-training/api-u-training/api-u-calendar/2013-events/12-03-13-dmech

American Petroleum Institute. (2013). *API Specification 16AR.* Retrieved from http://mycommittees.api.org/standards/ecs/sc16/TG7/Shared%20Documents/API-16AR%20Drill%20Through%20Equipmenr%20Repair%20and%20Remanufacturing%20V1%20-%2016AR%20meeting%20notes.pdf

American Petroleum Institute. (2013, April 1). Critical Equipment. *Recommended Practice for Development of a Safety and Environmental Management Program for Offshore Operations and Facilities*(3rd). Houston, TX, USA: American Petroleum Institute.

American Petroleum Institute. (2013, September). *Managing System Integrity for Hazardous Liquid Pipelines*. Retrieved January 5, 2015, from http://www.api.org/publications-standards-and-statistics/standards/whatsnew/publication-updates/new-pipeline-publications/api_rp_1160

American Petroleum Institute. (2013). *Specification for Wellhead and Christmas Tree Equipment.* Washington, DC: American Petroleum Institute. Retrieved December 30, 2014

American Petroleum Institute. (2013). *Specification for Wellhead and Christmas Tree Equipment.* Washington, DC: American Petroleum Institute. Retrieved December 30, 2014

American Petroleum Institute. (2014, October 12). *FAQs and Inquiries*. Retrieved October 12, 2014, from www.api.org: http://www.api.org/publications-standards-and-statistics/standards/faqs-and-inquiries

American Petroleum Institute. (2014). *Specification for Drill-through equipment repair and remanufacturing.* Washington, D.C.: American Petroleum Institute. Retrieved December 9, 2014, from http://mycommittees.api.org/standards/ecs/sc16/TG7/Shared%20Documents/API-16AR%20Drill%20Through%20Equipmenr%20Repair%20and%20Remanufacturing%20V1%20-%2016AR%20meeting%20notes.pdf

American Petroleum Institute. (2014). *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry.* Washington, DC: American Petroleum Institute. Retrieved October 9, 2014

American Petroleum Institute. (2014, December 5). *Spills & Accidental Response*. Retrieved December 5, 2014, from http://www.api.org/environment-health-and-safety/clean-water/oil-spill-prevention-and-response/spills-and-releases

Amtrak. (2014, September 23). *Programs.* Retrieved September 23, 2014, from http://www.amtrak.com/servlet/BlobServer?blobcol=urldata&blobtable=MungoBlobs&blobkey=id&blobwhere=1249200716867&blobheadervalue1=attachment;filename=Amtrak_UpdateKeyITPrograms-092009.pdf

Anonymous. (2015, January 20). Senior Oil and Gas Industry Participant. (B. L. Iddins, Interviewer)

Apache Corporation. (2013). *Form 10-Q (Quarterly Report).* Houston, Texas: Apache Corporation. Retrieved December 7, 2014, from http://www.otcmarkets.com/edgar/GetFilingPdf?FilingID=9598691

API. (2012). *Global Chemical Management | API Supporting SAICM.* Retrieved September 25, 2014, from API.org: http://www.api.org/environment-health-and-safety/health-safety/global-chemical-management/~/media/Files/EHS/Process-Safety/RASA-Brochure-ForWeb-HiRes.ashx

Aviation Safety Reporting System. (2014, September 30). *Aviation Safety Reporting System*. (A. S. System, Producer) Retrieved September 30, 2014, from Aviation Safety Reporting System: http://asrs.arc.nasa.gov/

Bhattacharyya, A. a. (2015, January 22). *www.ibm.com.* Retrieved January 22, 2015, from Scripting With Maximo: https://www.ibm.com/developerworks/community/forums/ajax/download/77777777-0000-0000-0000-000014772567/b8ec7d85-6a8d-4e25-bb89-d729c3322406/attachment_14772567_Scripting_with_Maximo.pdf

Boman, K. (2014, August 12). *BSEE: Better Standards Needed to Address Bolt, Connector Performance.* Retrieved December 5, 2014, from Rigzone.com: https://www.rigzone.com/news/oil_gas/a/134500/BSEE_Better_Standards_Needed_to_Address_Bolt_Connector_Performance/?all=HG2

Brad Edwards, J. G. (1999, April). *Effectiveness of ISO 14001 in the United States.* University of California Santa Barbara: Donald Bren School of Environmental Science And Management.

Bradley, D. (2015, January 29). *NatGas Pipe Incidents in Populated Areas Not Declining Under PHMSA Program*. Retrieved January 30, 2015, from http://www.naturalgasintel.com: http://www.naturalgasintel.com/articles/101194-natgas-pipe-incidents-in-populated-areas-not-declining-under-phmsa-program

Bureau of Environmental Safety and Enforcement. (2013). *Investigation of November 16, 2012, Explosion, Fire and Fatalities at West Delta Block 32 Platform E.* Bureau of Environmental Safety and Enforcement. Retrieved December 7, 2014

Bureau of Land Management. (2001, April 18). *Resource Notes.* Retrieved from Bureau of Land Management: http://www.blm.gov/nstc/resourcenotes/respdf/RN45.pdf

Bureau of Safety and Environmental Enforcement. (2013). *Boom Hoist Wire Rope Line Failure Results in Fatality High Island Area Block A557, Platform "A",.* New Orleans: Bureau of Safety and Environmental Enforcement. Retrieved December 7, 2014, from http://www.bsee.gov/uploadedFiles/BSEE/Enforcement/Accidents_and_Incidents/Panel_Investigation_Reports/HI-A557%20Panel%20Report%20-%20FINAL%20(1).pdf

Bureau of Safety and Environmental Enforcement. (2014, September 1). *About BSEE*. (B. o. Enforcement, Producer) Retrieved September 1, 2014, from Bureau of Safety and Environmental Enforcement: http://www.bsee.gov/About-BSEE/index/

Bureau, A. T. (2013, July 01). *www.skybrary.aero/bookshelf/books/2327.pdf*. Retrieved September 18, 2014, from www.skybrary.aero: http://www.skybrary.aero/bookshelf/books/2327.pdf

Business News Americas staff reporter. (2014, June 24). Lawmaker gives lowdown on Mexico hydrocarbons information agency. *Business News*, p. 1.

Canada, Newfoundland & Labrador Offshore Petroleum Board. (2014, September 30). *About C-NLOPB*. (N. L. Canada, Producer) Retrieved September 30, 2014, from Canada, Newfoundland& Labrador Offshore Petroleum Board: http://www.cnlopb.ca/abt_mandate.shtml

Canada-Nova Scotia Offshore Petroleum Board. (2014, September 30). *About Us*. (C.-N. S. Board, Producer) Retrieved September 30, 2014, from Canda-Nova Scotia Offshore Petroleum Board: http://www.cnsopb.ns.ca/about-us/about-us

Canada-Nova Scotia Offshore Petroleum Board. (2014, September 30). *Incident Reporting*. (C.-N. S. Board, Producer) Retrieved September 30, 2014, from Canada-Nova Scotia Offshore Petroleum Board: http://www.cnsopb.ns.ca/health-and-safety/incident-reporting

Canada-Nova Scotial Offshore Petroleum Board. (2014, September 30). *Life Cycle Approach*. (C.-N. S. Board, Producer) Retrieved September 30, 2014, from Canada-Nova Scotial Offshore Petroleum Board: http://www.cnsopb.ns.ca/about-us/what-we-do/life-cycle-approach

CCD Health Systems. (n.d.). *About CCD Systems*. Retrieved September 30, 2014, from http://www.ccdsystems.com/AboutCCD/HowtoReachUs.aspx

Centers for Disease Control. (2013, April 26). *Morbidty and Mortality Weekly Report - Fatal Injuries in Offshore Oil and Gas Operations — United States, 2003–2010.* Retrieved December 31, 2014, from www.cdc.gov: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6216a2.htm

Centers for Disease Control and Prevention. (2014, April 14). *About CDC*. Retrieved September 30, 2014, from CDC.gov: http://www.cdc.gov/about/organization/mission.htm

Centers for Disease Control and Prevention. (2014, 14 April). *Mission, Role , and Pledge*. Retrieved from Centers for Disease Control and Prevention: http://www.cdc.gov/about/organization/mission.htm

Christou , M., & Konstantinidou, M. (2012). *Safety of offshore oil and gas operations:Lessons from past accident analysis.* Ispra (VA), Italy: European Commission Joint Research Centre Institute for Energy and Transport.

Code of Federal Regulations (CFR). (2013, April 5). What hazards analysis criteria must my SEMS program meet? *30 CFR 250.1911*.

Code of Federal Regulations (CFR). (2015). *30 CFR 250.198: Documents Incorporated by Reference.* Washington: CFR.

(2014). *Commandant Instruction 16000.7B, Marine Safety Manual Volume II, Materiel Inspection.* Washington D.C. : U.S. Coast Guard .

(2013). *Commandant Instruction 3501, Casualty Reporting (CASREP) Procedures (Materiel) Manual.* Washington D.C. : U.S. Coast Guard .

(2007). *Commandant Instruction M10550.25, Electronics Manual.* Washington D.C. : U.S. Coast Guard .

(2014). *Commandant Instruction M11011.11, Civil Engineering Manual .* Washington D.C. : U.S. Coast Guard.

(2011). *Commandant Instruction M13020.1, Aeronautical Engineering Maintenance Manual .* Washington D.C. : U.S. Coast Guard .

(2008). *Commandant Instruction M16000.10A, USCG Marine Safety Manual, VOLUME V Investigation and Enforcement.* Washington D.C. : U.S. Coast Guard .

(2013). *Commandant Instruction M4500.5D., Personal Property Management Manual.* Washington D.C.: U.S. Coast Guard.

(2004). *Commandant Instruction M9000.6, Naval Engineering Manual.* Washington D.C. : U.S. Coast Guard.

(2013). *Commandant Instruction Manual 5000.10C Major Systems Aquisition Manual.* Washington D.C. : U.S. Coast Guard.

ConocoPhillips. (2014, September 24). *Life Cycle Thinking*. Retrieved September 24, 2014, from ConocoPhillips: http://www.conocophillips.com/sustainable-development/environment/Pages/life-cycle-thinking.aspx

ConocoPhillips. (2014). *What We Do*. Retrieved September 30, 2014, from http://www.conocophillips.com/what-we-do/Pages/default.aspx

ConocoPhillips. (2015, January 21). *Life Cycle Thinking*. Retrieved January 21, 2015, from http://www.conocophillips.com/sustainable-development/environment/Pages/life-cycle-thinking.aspx

ConocoPhillips. (n.d.). *Life Cycle Thinking*. Retrieved January 21, 2015, from http://www.conocophillips.com/sustainable-development/environment/Pages/life-cycle-thinking.aspx

Cooke, R. R. (2011). *Precursor Analysis for Offshore Oil and Gas Drilling:From Prescriptive to Risk-Informed Regulation.* Resources for the Future, Washington, D.C. Retrieved November 15, 2014, from http://www.rff.org/RFF/documents/RFF-DP-10-61.pdf

Crowley. (2014). *About Us*. Retrieved September 30, 2014, from http://www.crowley.com/About-Us/Company-Overview

Curry, T. (2015, February 3). Members Fume Over Delayed Oil Tank Car Rule. Washington, District of Colombia, U.S.A. Retrieved February 5, 2015, from http://blogs.rollcall.com/the-container/members-fume-over-delayed-oil-tank-car-rule/?dcz=

Defence Acquisition University. (2011, June 14). *DoD LCM and PSM Rapid Deployment Training.* Retrieved September 17, 2014, from United States Department of Defense: www.dau.mil/homepage documents/PSM RDT (v10 TTailored 14 Jun 11).pdf

Department of Defense. (1985, July 24). *Military Standard 2155*. Retrieved December 18, 2014, from http://www.halthass.co.nz/wp-content/uploads/standards/mil_std_2155.pdf

Department of Defense. (1995, December 11). DEPARTMENT OF DEFENSE HANDBOOK, FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION TAKEN. Washington, District of Columbia, United States. Retrieved February 9, 2015, from http://everyspec.com/

Department of Defense. (2015, May 4). *Failure Reporting, Analysis and Corrective Action Taken*. Retrieved May 5, 2015, from ASSIST - Quick Search: http://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=207200

Department of Health and Human Services. (2012, July 18). *Enterprise Performance Life Cycle Framework.* Retrieved from Centers for Disease Control and Prevention: http://www2a.cdc.gov/cdcup/library/hhs_eplc/EPLC_Framework_09-18-12.pdf

Department of Homeland Security. (2015, May 1). *PART 4—MARINE CASUALTIES AND INVESTIGATIONS*. Retrieved May 2015, from Electronic Code of Federal Regulations: http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=46:1.0.1.1.4

Department of Transportation. (2015, February 12). *Moving Ahead for Progress in the 21st Century Act (MAP-21)*. Retrieved February 26, 2015, from http://www.dot.gov/map21: http://www.dot.gov/map21

Department of Transportation FHWA. (1999, April 8). *FEDERAL-AID POLICY GUIDE*, Transmittal 25. Retrieved February 26, 2015, from http://www.fhwa.dot.gov/legsregs/directives/fapg/0500bsup.htm: http://www.fhwa.dot.gov/legsregs/directives/fapg/0500bsup.htm

Department of Transportation FHWA. (2014, July 8). *Strategic Highway Safety Plan (SHSP)*. Retrieved February 26, 2015, from http://safety.fhwa.dot.gov/hsip/shsp/: http://safety.fhwa.dot.gov/hsip/shsp/

Devaney, T. (2014, November 11). *Business groups brace for deluge of regs*. Retrieved January 30, 2015, from thehill.com: http://thehill.com/regulation/223769-biz-groups-brace-for-deluge-of-regulation

Devlin, G. (2014, June 27). *Product Life Cycle Management.* Cameron. Retrieved September 25, 2014, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=2&cad=rja&uact=8&ved=0CDAQFjAB&url=http%3A%2F%2Fmycommittees.api.org%2Fstandards%2Fecs%2Fsc18%2FMeeting%2520Materials%2F2013%2FWashington%2520Meeting%2520-%2520June%25202013%2FAttachment%2

Dunmade, I., & Rosentrater, K. (2009). A Treatise on the Application of Life Cycle Management Principles in Agriculture & Biological Engineering. *ASABE Annual International Meeting* (pp. 1-2). Reno, NV: American Society of Agricultural and Biological Engineers. Retrieved September 23, 2014, from http://naldc.nal.usda.gov/naldc/download.xhtml?id=40065&content=PDF

Eaton, C. (2013, November 13). *Feds cite Houston firm, contractors in fatal Gulf blast*. Retrieved December 7, 2014, from Fuelfix.com: http://fuelfix.com/blog/2013/11/13/safety-agency-cites-houston-firm-contractors-in-fatal-platform-blast/

Environmental Protection Agency. (1993, January). *Life Cycle Design Guidance Manual*. Retrieved January 12, 2015, from http://nepis.epa.gov/Adobe/PDF/30002PR5.PDF

Environmental Protection Agency. (2014, September 12). *About EPA*. (Environmental Protection Agency) Retrieved September 29, 2014, from Environmental Protection Agency: http://www2.epa.gov/aboutepa

EPIM. (2011, March 15). *License2Share.* Retrieved April 27, 2015, from http://www.npd.no/en/About-us/Collaboration-projects/EPIM/

European Environment Agency. (2015, February 25). *Major accident reporting system (MARS)*. Retrieved January 8, 2015, from http://www.eea.europa.eu/data-and-maps/data/external/major-accident-reporting-system-mars

European Environment Agency. (n.d.). *Major accident reporting system (MARS)*. Retrieved January 8, 2015, from http://www.eea.europa.eu/data-and-maps/data/external/major-accident-reporting-system-mars

EverySpec LLC. (2015). *MIL-STD-2155 (NOTICE 1), MILITARY STANDARD: FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION SYSTEM (FRACAS) (11 DEC 1995) [S/S BY MIL-HDBK-2155]*. Retrieved May 2015, from EverySpec: http://everyspec.com/MIL-STD/MIL-STD-2000-2999/MIL-STD-2155_NOTICE-1_24657/

Executive Office of Health and Human Services Department of Public Health Bureau of Healthcare Safety and Quality. (2011, April 4). User Manual Health Care Facility Monitoring System. Retrieved September 30, 2014, from http://www.mass.gov/eohhs/docs/dph/quality/healthcare/hcfrs-user-manual.pdf

Executive, O. a. (2014, December 8). Interview with senior Oil And Natural Gas Subject Matter Expert. (J. C. Hendrickson, Interviewer)

Executive, S. E. (2014, October 8). Chief Executive Officer. (J. C. Hendrickson, Interviewer)

ExxonMobil. (2014). *About us*. Retrieved September 30, 2014, from http://corporate.exxonmobil.com/en/company/about-us

ExxonMobil. (2014). *Up close: life cycle assessment*. Retrieved September 30, 2014, from http://corporate.exxonmobil.com/en/community/corporate-citizenship-report/managing-climate-change-risks/up-close-life-cycle-assessment?parentId=c7582d41-5b74-4e12-928d-643cd1ec8813

Fausset, R. a. (2010, September 2). *Los Angeles Times*. Retrieved December 7, 2014, from Oil platform explodes off Louisiana: http://articles.latimes.com/2010/sep/02/nation/la-na-oil-explosion-20100903

Federal Aviation Administration. (2014, September 29). *About FAA*. (F. A. Administration, Producer) Retrieved September 29, 2014, from Federal Aviation Administration: http://www.faa.gov/about/

Federal Aviation Administration. (2014, September 29). *FAA Aviation Safety Analysis and Sharing*. (F. A. Administration, Producer) Retrieved September 29, 2014, from Federal Aviation Administration: http://www.asias.faa.gov/pls/apex/f?p=100:1:14119288055667:::::

Federal Highway Administration. (n.d.). Retrieved from http://www.fhwa.dot.gov/index.cfm

Federal Highway Administration. (2003, April 1). *Highway Performance Monitoring System (HPMS)*. Retrieved February 10, 2015, from http://www.fhwa.dot.gov/policyinformation/hpms/hpmsprimer.cfm: http://www.fhwa.dot.gov/policyinformation/hpms.cfm

Federal Highway Administration. (2003, April 1). *Highway Performance Monitoring System (HPMS)*. Retrieved February 10, 2015, from Overview of HPMS for FHWA Field Offices – April 2003: http://www.fhwa.dot.gov/policyinformation/hpms/hpmsprimer.cfm

Federal Highway Administration. (2004, April 16). *Highway Performance Monitoring System (HPMS)*, Vol. 18. (The Urban Transportation Monitor) Retrieved February 10, 2015, from http://www.fhwa.dot.gov/policyinformation/hpms/volumeroutes/ch2.cfm#a37: http://www.fhwa.dot.gov/policyinformation/hpms/volumeroutes/

Federal Highway Administration. (2004, September 8). *Highway Performance Monitoring System Traffic Data for High Volume Routes: Best Practices and Guidelines.* Retrieved from https://www.fhwa.dot.gov/policyinformation/hpms/volumeroutes/hvr_revisedrpt.pdf

Federal Highway Administration. (2012, September 7). *About*. Retrieved from http://www.fhwa.dot.gov/about/

Federal Highway Administration. (2012, August 17). *Moving ahead for progress in the 21st century*. (F. H. Administration, Producer) Retrieved September 29, 2014, from Federal Highway Administration: https://www.fhwa.dot.gov/map21/summaryinfo.cfm

Federal Highway Administration. (2013). *Highway Performance Monitoring System (HPMS) - FHWA Review Guidlines.* Retrieved from http://www.fhwa.dot.gov/policyinformation/hpms/reviewguide.cfm

Federal Highway Administration. (2014, October 15). *Highway Safety Improvement Program*. Retrieved February 10, 2015, from http://safety.fhwa.dot.gov/safetealu/guides/guide051509.cfm: http://safety.fhwa.dot.gov/safetealu/guides/guide051509.cfm

Federal Highway Administration. (2014, September 29). *No-Federal Applications of the Highway Performance Monitoring System*. (F. H. Administration, Producer) Retrieved September 29, 2014, from Federal Highway Admisitration: No-Federal Applications of the Highway Performance Monitoring System

Federal Highway Administration. (2015, January 1). *About Highway Performance Monitoring System (HPMS)*. Retrieved February 11, 2015, from http://www.fhwa.dot.gov/policyinformation/hpms/abouthpms.cfm: http://www.fhwa.dot.gov/policyinformation/hpms.cfm

Federal Highway Administration. (2015, January 1). *Highway Performance Monitoring System (HPMS)*. Retrieved February 10, 2015, from http://www.fhwa.dot.gov/policyinformation/hpms.cfm: http://www.fhwa.dot.gov/ohim/hpmsarch.cfm

Federal Highway Administration. (2015, January 1). *Highway Performance Monitoring System (HPMS)*. Retrieved February 10, 2015, from http://www.fhwa.dot.gov/policyinformation/hpms/hpmsprimer.cfm: http://www.fhwa.dot.gov/policyinformation/hpms.cfm

Federal Highway Administration. (2015, January 1). *Highway Performance Monitoring System (HPMS)*. Retrieved April 10, 2015, from http://www.fhwa.dot.gov/policyinformation/hpms.cfm: http://www.fhwa.dot.gov/policyinformation/hpms.cfm

Federal Highway Administration. (n.d.). *Highway Performance Monitoring System Traffic Data For High Volume Routes: Best Practices and Guidelines Final Report.* Retrieved from http://www.fhwa.dot.gov/policyinformation/hpms/highvolumerep.cfm

Federal Highway Administration. (n.d.). *Highway Performance Monitoring System Traffic Data For High Volume Routes: Best Practices and Guidelines Final Report.* Retrieved from http://www.fhwa.dot.gov/policyinformation/hpms/highvolumerep.cfm

Federal Railroad Administration. (2007, October). Collision Hazard Analysis Guide: Commuter and Intercity Passenger Rail Service. Washington, District of Columbia, U.S.A. Retrieved from http://www.fra.dot.gov/Elib/Details/L03191

FHWA. (2012, July 17). *A Summary of Highway Provisions - MAP-21 - Moving Ahead for Progress in the 21st Century*. Retrieved February 10, 2015, from http://www.fhwa.dot.gov/map21/summaryinfo.cfm.

FHWA. (2012, July 17). *A Summary of Highway Provisions - MAP-21 - Moving Ahead for Progress in the 21st Century*. Retrieved February 10, 2015, from http://www.fhwa.dot.gov/map21/summaryinfo.cfm: http://www.fhwa.dot.gov/map21/summaryinfo.cfm

Find the Best. (2014). *Reliasoft Corporation Contracts*. Retrieved December 31, 2014, from http://government-contracts.findthebest.com/d/b/Reliasoft-Corporation

Five Winds International. (2004, August). *Gas to Liquids Life Cycle Assessment Synthesis Report*. Retrieved January 14, 2015, from http://www.sydneypeakoil.com/davek/GTL_LCA_Synthesis_Report.pdf

Florida Power & Light Company, St Lucie Nuclear Plant. (2005). *Licensee Event Report 2005-006.* NRC Form 366A. Retrieved from http://pbadupws.nrc.gov/docs/ML0535/ML053570224.pdf

Foss. (2014). *About Us*. Retrieved September 30, 2014, from http://www.foss.com/about-us/

Freeby, G. A. (2013, August 23). *Bridge Inspection Manual*. Retrieved from Chapter 7, Section 4: Bridge Management System: http://onlinemanuals.txdot.gov/txdotmanuals/ins/bridge_management_system.htm

Fuetsch, M. (2015, January 22). DeFazio Blasts DOT Over Failure to Finalize Tank Car Rule, Calls for PHMSA Audit. *Transportation Topics: The Newspaper of Trucking and Freight Transportation*. Washington, District of Colombia. Retrieved February 5, 2015, from http://www.ttnews.com/articles/basetemplate.aspx?storyid=37125

GL Noble Denton. (2010, December). *Review and Comparison of Petroleum Safety Regulatory Regimes for the Commission for Energy Regulation.* Retrieved February 16, 2015, from https://www.cer.ie/docs/000458/cer11015.pdf

Glossary of Defense Acquisition Acronyms and Terms. (2015, January 7). Retrieved from Department of Defense, Defense Acquisition University: https://dap.dau.mil/glossary/Pages/Default.aspx

Gordon R. Toevs, J. J. (2011, August). *Assesment, Inventory, and Monitoring Strategy For Integrated Renewable Resources Management.* Retrieved from Bureau of Land Management: http://www.blm.gov/pgdata/etc/medialib/blm/wo/Information_Resources_Management/policy/ib_attachments/2012.Par.53766.File.dat/IB2012-080_att1.pdf

Government Accounting Office. (2011, April 1). *23 CFR 500.108 - SMS*. Retrieved February 26, 2015, from http://www.gpo.gov/fdsys/granule/CFR-2011-title23-vol1/CFR-2011-title23-vol1-sec500-108: http://www.gpo.gov/fdsys/granule/CFR-2011-title23-vol1/CFR-2011-title23-vol1-sec500-108

Graham, D. a. (2012). *Experiences of Test Automation: Case Studies of Software Test Automation.* Upper Saddle River, NJ : Addison-Wesley.

Habich, N. (2001, April 18). Ecological Site Inventory Query (Inventory Data System). *Resource Notes*, pp. 1-2.

Health and Safety Executive. (2014). *KP4 Programme*. Retrieved September 23, 2014, from Health and Safety Executive: http://www.hse.gov.uk/offshore/ageing/kp4-programme.htm

Health and Safety Executive. (2014). *Offshore Installations and Wells (design and construction, etc) Regulations 1996*. Retrieved from Health and Safety Executive: http://www.hse.gov.uk/offshore/notices/on_37.htm

Health and Safety Executive. (2014). *RIDDOR - Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013*. Retrieved from Health and Safety Executive: http://www.hse.gov.uk/riddor/

Health and Safety Executive. (2014). *Types of reportable incidents*. Retrieved from Health and Safety Executive: http://www.hse.gov.uk/riddor/reportable-incidents.htm

Hudson, B. G. (2010, November). *Extending the life of an ageing offshore facility, Society of Petroleum Engineers 138654*. Retrieved January 6, 2015, from http://www04.abb.com/global/seitp/seitp202.nsf/0/001a63cdd274a7d5c12577d60026c217/$file/ADIPEC+paper+-+Extending+the+life+of+an+ageing+offshore+facility.pdf

IADC. (2014, September 30). *About*. Retrieved September 30, 2014, from http://www.iadc.org/about/

IADC. (2014). *About*. Retrieved September 30, 2014, from http://www.iadc.org/about/

IADC. (2014). *IADC ISP PROGRAM - 5 Year Summary Report, Lost Time and Total Recordable Indcidence/Frequency Rate.*

Ib Larsen, K. N. (2013, May 13). Consolidated Act on Safety, etc. for Offshore Installations for Exploration, Extraction and Transport of Hydrocarbons (Offshore Safety Act). Netherlands. Retrieved September 30, 2014, from http://www.ens.dk/sites/ens.dk/files/oil-gas/health-safety/Rules_oil_gas/ca2013_0520e_offshore_safety_act.pdf

(2009). *Independent Evaluation USCG Prevention Program.* Arlington, VA: Homeland Security Institute.

Info Mimet. (2015, Febuary 25). *Databases Proprietary*. Retrieved January 8, 2015, from Major Hazard Incident Data Service: http://w3.cetem.gov.br/infomimet/vercadastro1_en.asp?count=131

Info Mimet. (n.d.). *Databases Proprietary*. Retrieved January 8, 2015, from Major Hazard Incident Data Service: http://w3.cetem.gov.br/infomimet/vercadastro1_en.asp?count=131

Infostat. (n.d.). *RIMDrill Overview*. Retrieved December 16, 2014, from http://infostatsystems.com/drilling-contactors-rimdrill/rimdrill-for-drilling-contactors

Institute of Asset Management. (2008). *What is PAS55?* Retrieved January 6, 2015, from https://theiam.org/products-and-services/pas-55/what-pas55

Institute of Asset Management. (2008, January 6). *What is PAS55?* Retrieved January 6, 2015, from https://theiam.org/products-and-services/pas-55/what-pas55

Intelex. (2015, January 8). *RIDDOR*. Retrieved January 8, 2015, from http://www.intelex.com/Injury_Reporting___RIDDOR-981-3product.aspx

Intelex. (n.d.). *RIDDOR*. Retrieved January 8, 2015, from http://www.intelex.com/Injury_Reporting___RIDDOR-981-3product.aspx

Intelex Technologies Inc. (2015, January 8). *RIDDOR*. Retrieved January 8, 2015, from http://www.intelex.com/Injury_Reporting___RIDDOR-981-3product.aspx

International . (2014, December 31). *ISO/TS 15926-8:2011 - Industrial automation systems and integration -- Integration of life-cycle data for process plants including oil and gas production facilities -- Part 8: Implementation methods for the integration of distributed systems: Web*

Ontolog. Retrieved December 31, 2014, from www.iso.org: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52456

International Association of Drilling Contractors. (2009). *Dropped Drawworks Platform.* International Association of Drilling Contractors. Retrieved from http://www.iadc.org/wp-content/uploads/2014/02/sa-09-13.pdf

International Association of Drilling Contractors. (2009, July 27). *Health, Safety, and Environmental Case Guidelines for Land Drilling Units.* Retrieved December 19, 2014, from IADC HSE Guidelines: http://www.iadc.org/wp-content/uploads/doc-Land-Drilling-HSE-Guidelines.pdf

International Association of Drilling Contractors. (2012, February 20). *CCGD8 Marine Safety Bulletin dated 6 February 2012, Reporting Requirements – Failure of Critical Systems*. Retrieved December 17, 2014, from http://www.iadc.org/wp-content/uploads/20120220-to-CCGD8-on-MSIB.pdf

International Association of Drilling Contractors. (2014, September 30). *About*. Retrieved September 30, 2014, from http://www.iadc.org/about/

International Association of Drilling Contractors. (2014, September 30). *About*. Retrieved September 30, 2014, from http://www.iadc.org/about/

International Association of Drilling Contractors. (2014, January 1). *Appendix to Health, Safety and Environment Case Guidelines for Offshore Drilling Contractors*, 3.5. Retrieved December 31, 2014, from http://www.iadc.org/wp-content/uploads/doc-MODU-HSE-Case-Guidelines-Appendices.pdf

International Association of Drilling Contractors. (2014). *Drilling Lexicon*. Retrieved December 19, 2014, from Near-Miss: http://www.iadclexicon.org/near-miss/

International Association of Drilling Contractors. (2014, December 19). *Drilling Lexicon*. Retrieved December 19, 2014, from Near-Miss: http://www.iadclexicon.org/near-miss/

International Association of Drilling Contractors. (2014, January 1). *Health, Safety, and Environmental Case Guideline for Mobile Offshore Drilling Units*, 3.5. Retrieved December 19, 2014, from HSE Guidelines : http://www.iadc.org/wp-content/uploads/doc-MODU-HSE-Case-Guidelines.pdf

International Association of Drilling Contractors. (2014). *HSE Management Objectives*. Retrieved December 31, 2014, from IADC Drilling Lexicon: http://www.iadclexicon.org/hse-management-objectives/

International Association of Drilling Contractors. (2014, Decemeber 31). *HSE Management Objectives*. Retrieved December 31, 2014, from IADC Drilling Lexicon: http://www.iadclexicon.org/hse-management-objectives/

International Association of Drilling Contractors. (2014). *IADC HSE Case Guidelines*. Retrieved December 16, 2014, from http://www.iadc.org/iadc-hse-case-guidelines/

International Association of Drilling Contractors. (2014). *IADC Incidents Statistics Program (ISP)*. Retrieved December 16, 2014, from http://www.iadc.org/isp/

International Association of Drilling Contractors. (2014). *Internal Explosion Ruptures Crown Mounted Compensator Piping.* International Association of Drilling Contractors. Retrieved from http://www.iadc.org/wp-content/uploads/SA-14-01.pdf

International Association of Drilling Contractors. (2014, September 24). *International Association of Drilling Contractors Lexicon*. Retrieved September 24, 2014, from International Association of Drilling Contractors: http://www.iadclexicon.org/hse-critical-system-equipment/

International Association of Drilling Contractors. (2014). *MODU HSE Case*. Retrieved December 31, 2014, from IADC Drilling Lexicon.

International Association of Drilling Contractors. (2014, May 21). *Well Control Committee Meeting*. Retrieved December 16, 2014, from http://www.iadc.org/wp-content/uploads/2014/09/21-May-2014-Well-Control-Cmte.-Mtg.-Approved-Minutes.pdf

International Association of Drilling Contractors. (2015, February 27). *IADC HSE Case Guidelines*. Retrieved December 16, 2014, from http://www.iadc.org/iadc-hse-case-guidelines/

International Association of Oil and Gas Producers. (2010, March). *Regulators' Use of Standards.* Retrieved February 16, 2015, from http://www.ogp.org.uk/pubs/426.pdf

International Atomic Energy Agency. (2015, January 12). *IRS - International Reporting System*. Retrieved January 12, 2015, from IAEA.org: http://www-ns.iaea.org/reviews/op-safety-reviews.asp?s=2&l=15#irs

International Business Machines. (2014, December 15). *IBM Maximo Asset Management solutions for the oil and gas industry (Brochure-USEN).* Retrieved December 15, 2014, from http://www-01.ibm.com/common/ssi/cgi-bin/ssialias?infotype=PM&subtype=BR&appname=SWGE_TI_EA_USEN&htmlfid=TIB14011USEN&attachment=TIB14011USEN.PDF

International Business Machines. (2014, October 15). *Maximo for Oil and Gas*. Retrieved October 15, 2014, from http://www-03.ibm.com/software/products/en/maximo-for-oil-and-gas

International Business Machines. (2015, January 21). *Maximo Spatial Asset Management*. Retrieved January 21, 2015, from http://www-03.ibm.com/software/products/en/maxispatassemana

International Business Machines. (n.d.). *View Pricing and Buy*. Retrieved December 15, 2015, from https://www-112.ibm.com/software/howtobuy/buyingtools/paexpress/Express?P0=E1&part_number=D0GZB

LL,D0GZFLL,D0GZHLL,D0GZLLL ,D0S8ZLL ,D0S92LL&catalogLocale=en_US&Locale=en_US&country=USA&PT=jsp&CC=USA&VP=&TACTICS =&S_TACT=&S_CMP=&brand=SB04

International Organization for Standardization. (1997, June 15). *ISO 14040*. Retrieved January 28, 2015, from Environmental Management - Life cycle assessment - Principles and framework: http://web.stanford.edu/class/cee214/Readings/ISOLCA.pdf

International Organization for Standardization. (2000, March 15). *ISO 14041*. Retrieved January 30, 2015, from Environmental management—Life cycle assessment—Examples of application to goal and scope definition and inventory analysis: http://www.pqm-online.com/assets/files/standards/iso_tr_14049-2000.pdf

International Organization for Standardization. (2006, July 1). *ISO 14044*. Retrieved January 28, 2015, from Environmental Management - Life cycle assessment - Requirements and Guidelines: http://www.bae.uky.edu/montross/bae506/ISO%20EN%2014044-2006.pdf

International Organization For Standardization. (2007). *Petroleum Petrochemical and Natural Gas Industries - Collection and Exchange of Reliability and Maintenance Data for Equipment.* Geneva: International Organization For Standardization. Retrieved December 29, 2014

International Organization For Standardization. (2007). *Petroleum, Petrochemical and Natural Gas Industries - Collection and Exchange of Reliability and Maintenance Data for Equipment.* Geneva: International Organization For Standardization. Retrieved December 29, 2014

International Organization for Standardization. (2008). *ISO 9001 - Quality Management Systems Requirements.* Geneva: International Organization For Standardization. Retrieved December 29, 2014

International Organization for Standardization. (2009). *Annual Report 2009.* ISO. Retrieved from http://www.iso.org/iso/annual_report_2009.pdf

International Organization For Standardization. (2014, October 12). *How Does ISO Develop Standards?* Retrieved October 12, 2014, from http://www.iso.org/: http://www.iso.org/iso/home/standards_development.htm

International Organization for Standardization. (2014, Decemeber 30). *ISO 14000 - Environmental management*. Retrieved December 30, 2014, from ISO Management System Standards: http://www.iso.org/iso/iso14000

International Organization For Standardization. (2014, October 31). *ISO 15926-2:2003 - Industrial automation systems and integration -- Integration of life-cycle data for process plants including oil and gas production facilities -- Part 2: Data model*. Retrieved October 31, 2014, from http://www.iso.org: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=29557

International Organization for Standardization. (2014, December 31). *ISO 17776:2000*. Retrieved December 31, 2014, from http://www.iso.org/iso/catalogue_detail.htm?csnumber=31534

International Organization For Standardization. (2014, December 30). *ISO 20815:2008 Petroleum, petrochemical and natural gas industries -- Production assurance and reliability management*. Retrieved December 30, 2014, from www.iso.org: https://www.iso.org/obp/ui/#iso:std:39744:en

International Organization For Standardization. (2014, December 31). *ISO/TS 15926-7:2011 - Industrial automation systems and integration -- Integration of life-cycle data for process plants including oil and gas production facilities -- Part 7: Implementation methods for the integration of distributed systems: Template met*. Retrieved December 31, 2014, from www.iso.org: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52455

International Organization For Standardization. (2014, December 31). *ISO/TS 15926-8:2011 - Industrial automation systems and integration -- Integration of life-cycle data for process plants including oil and gas production facilities -- Part 8: Implementation methods for the integration of distributed systems: Web Ontolog*. Retrieved December 31, 2014, from www.iso.org: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52456

International Organization for Standardization. (2014, December 31). *Online Browing Platform (OBP) ISO 15663-3:2001(en) Petroleum and natural gas industries — Life-cycle costing — Part 3: Implementation guidelines*. Retrieved December 31, 2014, from www.iso.org: https://www.iso.org/obp/ui/#iso:std:iso:15663:-3:ed-1:v1:en

International Organization for Standardization. (2014, December 31). *Online Browsing Platform (OBP) ISO 15663-1:2000(en) Petroleum and natural gas industries — Life cycle costing — Part 1: Methodology*. Retrieved December 31, 2014, from www.iso.org: https://www.iso.org/obp/ui/#iso:std:28625:en

International Organization For Standardization. (2014, December 31). *Online Browsing Platform (OBP) ISO 15663-2:2001(en) Petroleum and natural gas industries — Life-cycle costing Part 2: Guidance on appilication of methodology and calculation methods*. Retrieved December 31, 2014, from www.iso.org: https://www.iso.org/obp/ui/#iso:std:iso:15663:-2:ed-1:v1:en

International Organization For Standardization. (2014, December 30). *Online Browsing Platform: ISO/TS 29001:2010 -Petroleum, petrochemical and natural gas industries -- Sector-specific quality management systems -- Requirements for product and service supply organizations*. Retrieved December 30, 2014, from www.iso.org: https://www.iso.org/obp/ui/#iso:std:55499:en

International Organization For Standardization. (2014, December 31). *Technology Moves On - What about ISO Standards?* Retrieved December 31, 2014, from www.iso.org: http://www.iso.org/iso/home/faqs/faqs_standards.htm

International Organization for Standardization. (2015, February 27). *ISO 14000 - Environmental management*. Retrieved December 30, 2014, from ISO Management System Standards: http://www.iso.org/iso/iso14000

International Organization for Standardization. (2015, February 27). *ISO 17776:2000*. Retrieved December 31, 2014, from http://www.iso.org/iso/catalogue_detail.htm?csnumber=31534

International Organization for Standardization. (n.d.). *ISO 14000 - Environmental management*. Retrieved December 30, 2014, from ISO Management System Standards: http://www.iso.org/iso/iso14000

International Organization for Standardization. (n.d.). *ISO 17776:2000*. Retrieved December 31, 2014, from http://www.iso.org/iso/catalogue_detail.htm?csnumber=31534

International Organization of Standardization. (2014). *ISO 13533:2001 - Petroleum and natural gas industries - Drilling and production equipment - Drill-through equipment.* ISO. Retrieved from http://www.iso.org/iso/catalogue_detail.htm?csnumber=35412

International Standardization Organization. (2014, September 30). *About ISO*. Retrieved September 30, 2014, from International Organization of Standards: http://www.iso.org/iso/home/about.htm

ISO. (2006, July 7). *ISO Standards for Life Cycle Assessment*. Retrieved September 25, 2014, from http://www.iso.org/iso/home/news_index/news_archive/news.htm?refid=Ref1019

ISO. (2006). *ISO Standards for Life Cycle Assessment to Promote Sustainable Development*. Retrieved September 24, 2014, from http://www.iso.org/iso/home/news_index/news_archive/news.htm?refid=Ref1019

ISO. (2010). *ISO 14040:2006Environmental Management -- Life Cycle Assessment -- Principles and Framework*. Retrieved September 24, 2014, from http://www.iso.org/iso/catalogue_detail?csnumber=37456

ISO. (2014, September 30). *About ISO*. Retrieved September 30, 2014, from International Organization of Standards: http://www.iso.org/iso/home/about.htm

John, S. (2014, December 16). American Bureau of Shipping Oil and Natural Gas Senior Engineer. (M. Sculley, Interviewer)

John, S. (2014, December 16). American Bureau of Shipping Oil and Natural Gas Senior Engineer. (M. Sculley, Interviewer) Retrieved 2014

Joy Global. (2014). *About Us*. Retrieved September 30, 2014, from http://www.joyglobal.com/Joy-Global/About-Joy-Global.htm

Joy Mining. (2014, September 26). *Joy's Life Cycle Management.* Retrieved September 26, 2014, from http://www.joy.com/JoyMining/PerspectivesMagazine/Perspectives_Vol11no1.pdf

Kusnetz, N. (2011, February 9). EPA Wants to Look at Full Lifecycle of Fracking in New Study. Propublica. Retrieved September 30, 2014, from http://www.propublica.org/article/epa-wants-to-look-at-full-lifecycle-of-fracking-in-new-study

Lawton, R. H. (1992, 9 March). *Report of Undesirable Events.* Retrieved from Bureau of Land Management: http://www.blm.gov/pgdata/etc/medialib/blm/mt/blm_programs/energy/oil_and_gas/operations/ntls.Par.47937.File.dat/ntl3mt.pdf

Lawton, R. H. (1992 Robert H. Lawton). *Report of Undesirable Events.* UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT Montana State Office. Retrieved from http://www.blm.gov/pgdata/etc/medialib/blm/mt/blm_programs/energy/oil_and_gas/operations/ntls.Par.47937.File.dat/ntl3mt.pdf

Leicestershire Partnership NHS Trust. (2013, October). *Reporting Flow Chart.* Retrieved April 2015, from RIDDOR.

Levine, J. (2014, August 4).

License2Share. (2015). *Why use L2S?* Retrieved April 27, 2015, from http://www.license2share.com/why-use-l2s/category140.html

Liming, J. (2015, February 13). NRC Regulatory Q&A Call. (R. I. Brandon Lee, Interviewer) Retrieved 2015

Liming, J. (2015, February 13). NRC Regulatory Q&A Call. (R. I. Brandon Lee, Interviewer)

Liming, J. (2015, February 13). The Nuclear Regulatory Commission's Oversight Landscape. (B. Lee, Interviewer)

(2013). *Marine Accident Reporting, Investigations, and Enforcement in the United States Coast Guard.* Washington D.C. : Department of Homeland Security, Office of Inspector General .

Massachusetts Department of Public Health. (2014, September 30). *Department of Public Health*. (M. D. Health, Producer) Retrieved September 30, 2014, from Executive Office of Health and Human Services: http://www.mass.gov/eohhs/gov/departments/dph

Mine Safety and Health Administration. (2014, September 24). *Equipment Safety and Health Concerns. Health Related Accidents*. Retrieved September 24, 2014, from Mine Safety and Health Administration: http://www.msha.gov/equipmentsafety/equipmentaccidents.asp

Mine Safety and Health Administration. (2014, September 29). *Hazard Communication Final Rule Single Source Page*. Retrieved September 29, 2014, from Mine Safety and Health Administration: http://www.msha.gov/hazcom/hazcom.htm

Minmier, J. (2014). Featured Remarks for the 2014 IADC Asset Integrity and Reliability Conference. *IADC Asset Integrity and Reliability Conference* (p. n. pag.). Houston: IADC. Retrieved September 25, 2014, from http://www.iadc.org/wp-content/uploads/2014/08/IADC-2014-Chairman-Jay-Minmier-Featured-address-for-IADC-Asset-Integrity-Reliability-Conference_Slides.pdf

National Energy Board. (2014, September 25). *2000-2013 Pipeline Incident Reporting*. Retrieved September 25, 2014, from http://www.neb-one.gc.ca/clf-nsi/rsftyndthnvrnmnt/sfty/pplnncdntgrprtng/pplnncdts/pplnncdts-eng.html

National Energy Board. (2014, September 25). *The NEB's Lifecycle Approach to Protecting the Environment*. Retrieved September 25, 2014, from http://www.neb-one.gc.ca/clf-nsi/rsftyndthnvrnmnt/nvrnmnt/lfcclpprch/lfcclpprch-eng.html

National Energy Board. (2014, September 25). *Who We Are & Our Governance*. Retrieved September 25, 2014, from NEB-one.gc.ca: http://www.neb-one.gc.ca/clf-nsi/rthnb/whwrndrgvrnnc/whwrndrgvrnnc-eng.html

National Highway Traffic Safety Administration. (2014, September 29). *Fatality Analysis Reporting System*. (N. H. Administration, Producer) Retrieved September 29, 2014, from National Highway Traffic Safety Administration: http://www.nhtsa.gov/FARS

National Highway Traffic Safety Administration. (2014, September 29). *Trucks in Fatal Accidents and Buses in Fatal Accidents*. (N. H. Administration, Producer) Retrieved September 2014, 2014, from National Highway Traffic Safety Administrsation: http://www.nhtsa.gov/FARS

National Highway Traffic Safety Administration. (2014, 29 September). *Trucks in Fatal Accidents and Buses in Fatal Accidents*. (National HighwayTraffic Safety Administration) Retrieved September 29, 2014, from National Highway Traffic Safety Administration: http://www.nhtsa.gov/Data/Fatality+Analysis+Reporting+System+(FARS)/Trucks+in+Fatal+Accidents+(TIFA)+and+Buses+in+Fatal+Accidents+(BIFA)

National Offshore Petroleum Safety Authority. (2008, May 27). *FACILITY INTEGRITYTOPSIDES MAINTENANCE SYSTEM ONSHORE INTERVIEWS.* Retrieved September 26, 2014, from www.nopsema.gov.au: http://www.nopsema.gov.au/assets/Forms/N-06100-FM0435-Prompt-Sheet-Topsides-maintenance-system-onshore-interviews.pdf

National Transportation Safety Board. (2014, September 30). *Accident Reporting*. (N. T. Board, Producer) Retrieved September 30, 2014, from National Transportation Safety Board: http://www.ntsb.gov/investigations/reports.html

Naval Educational And Training Professional Development Center. (2013, May). Electronics Technicial Supervisor. Pensacola, Florida: Naval Educational And Training Professional Development Center. Retrieved February 17, 2015, from http://navybmr.com/study%20material%203/NAVEDTRA%2014347.pdf

Netherlands Oil and Gas Exploration Production Association. (2014, September 30). *Download Guidelines*. (N. O. Association, Producer) Retrieved September 30, 2014, from Netherlands Oil and Gas Exploration Production Association: http://www.nogepa.nl/en-us/download-guidelines/

New Zealand Government Parlimentary Council Office. (2013, June 5). *Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013*. Retrieved November 24, 2014, from www.legislation.govt.nz: http://www.legislation.govt.nz/regulation/public/2013/0208/15.0/DLM5202524.html

New Zealand Legislation. (2013, May 20). Health and Safety in Employment . Wellington , New Zealand. Retrieved September 30, 2014, from file:///C:/Users/AnDe/Downloads/Health%20and%20Safety%20in%20Employment%20Petroleum%20Exploration%20and%20Extraction%20Regulations%202013%20(1).pdf

New Zealand Legislation. (2013, May 20). *Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013*. Retrieved December 31, 2014, from http://legislation.govt.nz/regulation/public/2013/0208/latest/whole.html#DLM5202524

New Zealand Legislation. (2013, May 20). Regulations for Safety Case. Wellington, New Zealand. Retrieved from New Zealand Legislation: http://www.legislation.govt.nz/regulation/public/2013/0208/latest/DLM5202531.html

NL Olie- en Gasportaal. (2014, September 30). *Welcome*. Retrieved September 30, 2014, from http://www.nlog.nl/

NOGEPA. (2014). *Download Guidelines*. Retrieved September 30, 2014, from http://www.nogepa.nl/en-us/download-guidelines/

NOGEPA. (2014). *Organisation*. Retrieved from http://www.nogepa.nl/en-us/nogepa/organisation/

NOLAND v. ENERGY RESOURCES TECHNOLOGY, INC., Civil Action No. 3:12-CV-00330. (United States District Court, S.D. Texas, Galveston Division. January 16, 2013).

NOPSEMA. (2014, January 1). *nopsema-jurisdiction*. Retrieved September 26, 2014, from www.nopsema.gov.au: http://www.nopsema.gov.au/about/nopsema-jurisdiction/

Nuclear Regulatory Commission . (2009, May 21). MEMORANDUM: SUBMITTAL TO INCIDENT REPORTING SYSTEM TO WEB BASED SYSTEM. Rockville, Maryland, United States: U.S. Nuclear Regulatory Commission . Retrieved February 21, 2015, from http://pbadupws.nrc.gov/docs/ML0914/ML091410454.pdf

Nuclear Regulatory Commission. (2000, October). *Event Reporting Guidelines 10 CFR 50.72 and 50.73*. Retrieved February 6, 2015, from http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1022/r2/sr1022r2.html

Nuclear Regulatory Commission. (2000, December). *NRC Form 361*. Retrieved February 11, 2015, from Reactor Plant Notification Worksheet: http://www.nrc.gov/reading-rm/doc-collections/forms/nrc361.pdf

Nuclear Regulatory Commission. (2007, September). *Common-Cause Failure Database and Analysis System: Event Data Collection, Classification, and Coding*. Retrieved February 2015, from NUREG/CR-6268, Rev. 1: http://pbadupws.nrc.gov/docs/ML0729/ML072970404.pdf

Nuclear Regulatory Commission. (2008, February 21). *MEMORANDUM: SUBMITTED TO INCIDENT REPORTING SYSTEM VIA WEB-BASED SYSTEM*. Rockville, Maryland, United States: U.S. Nuclear Regulatory Commission. Retrieved February 12, 2015, from http://pbadupws.nrc.gov/docs/ML0805/ML080510438.pdf

Nuclear Regulatory Commission. (2010, September 30). *Fire Event Data from Licensee Event Reports*. Retrieved February 6, 2015, from http://catalog.data.gov/dataset/fire-event-data-from-licensee-event-reports

Nuclear Regulatory Commission. (2010, September 30). *Fire Event Data from Licensee Event Reports*. Retrieved February 6, 2015, from http://catalog.data.gov/dataset/fire-event-data-from-licensee-event-reports

Nuclear Regulatory Commission. (2011, March 4). *Easy Searching for Licensee Event Reports*. Retrieved February 6, 2015, from http://public-blog.nrc-gateway.gov/2011/03/04/easy-searching-for-licensee-event-reports/

Nuclear Regulatory Commission. (2013, September 23). *Common Cause Failure Database*. Retrieved February 6, 2015, from http://nrcoe.inel.gov/resultsdb/CCFDB/

Nuclear Regulatory Commission. (2013, September 23). *Common Cause Failure Database*. Retrieved February 6, 2015, from http://nrcoe.inel.gov/resultsdb/CCFDB/

Nuclear Regulatory Commission. (2014, July 10). *10 CFR 50.72*. Retrieved February 6, 2015, from Immediate notification requirements for operating nuclear power reactors: http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0072.html

Nuclear Regulatory Commission. (2014, July 10). *10 CFR 50.73*. Retrieved February 6, 2015, from Licensee event report system: http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0073.html

Nuclear Regulatory Commission. (2014, September 26). *About Emergency Response*. Retrieved February 9, 2015, from http://www.nrc.gov/about-nrc/emerg-preparedness/respond-to-emergency.html

Nuclear Regulatory Commission. (2014, September 23). *Common Cause Failure Database*. Retrieved February 6, 2015, from http://nrcoe.inel.gov/resultsdb/CCFDB/

Nuclear Regulatory Commission. (2014, May 15). *List of Power Reactor Units*. Retrieved February 11, 2015, from http://www.nrc.gov/reactors/operating/list-power-reactor-units.html

Nuclear Regulatory Commission. (2014, February). *NRC Form 366*. Retrieved February 6, 2015, from Licensee Event Report (LER) : http://www.nrc.gov/reading-rm/doc-collections/forms/nrc366info.html

Nuclear Regulatory Commission. (2015, February 25). *Common-Cause Failure Database and Analysis Software and Reliability and Availability Data System*. Retrieved February 6, 2015, from https://nrcoe.inel.gov/secure/ccfdb/index.cfm

Nuclear Regulatory Commission. (2015, February 11). *Licensee Event Report Search (LERSearch)* . Retrieved February 6, 2015, from https://lersearch.inl.gov/Entry.aspx

Nuclear Regulatory Commission. (2015, January 28). NRC Regulations: Title 10 Code of Federal Regulations. *NRC Regulations*. Washington, District of Colombia, USA. Retrieved Februrary 17, 2015, from http://www.nrc.gov/reading-rm/doc-collections/cfr/

Nuclear Regulatory Commission. (May, 2014 15). *List of Power Reactor Units*. Retrieved February 11, 2015, from http://www.nrc.gov/reactors/operating/list-power-reactor-units.html

Nuclear Regulatory Commission. (September, 30 2010). *Fire Event Data from Licensee Event Reports*. Retrieved February 6, 2015, from http://catalog.data.gov/dataset/fire-event-data-from-licensee-event-reports

Occupation Health and Safety Administration. (2014, September 23). *OSHA Strategic Plan.* Retrieved September 23, 2014, from Department of Labor/Occupational Safety and Health Administration: https://www.osha.gov/archive/oshinfo/strategic/pg4.html

Occupational Health and Safety Administration. (2009, May 20). *Oil and Gas Well Drilling and Servicing eTool*. Retrieved September 24, 2014, from www.osha.gov: https://www.osha.gov/SLTC/etools/oilandgas/index.html

Occupational Health and Safety Management (U.K.). (2014, Decemeber 31). *BS OHSAS 18001 Occupational Health and Safety Management*. Retrieved December 31, 2014, from British Standards Institute: http://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/

Occupational Health and Safety Management (U.K.). (2014, Decemeber 31). *BS OHSAS 18001 Occupational Health and Safety Management*. Retrieved December 31, 2014, from British Standards Institute: http://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/

Occupational Health and Safety Management (U.K.). (n.d.). *BS OHSAS 18001 Occupational Health and Safety Management*. Retrieved December 31, 2014, from British Standards Institute: http://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/

Occupational Health and Safety Management (UK). (n.d.). *BS OHSAS 18001 Occupational Health and Safety Management*. Retrieved December 31, 2014, from British Standards Institute: http://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/

Occupational Safety and Health Administration. (2014, September 20). *About OSHA*. Retrieved September 20, 2014, from OSHA: https://www.osha.gov/about.html

Occupational Safety and Health Administration. (n.d.). *Establishment Search*. (O. S. Administration, Producer) Retrieved September 29, 2014, from Occupational Safety and Health Adminstration: https://www.osha.gov/pls/odi/establishment_search.html

Office of the Auditaor General, New Zealand. (2010, April 21). *Asset management for public entities: Learning from local government examples*. Retrieved Septemeber 19, 2014, from auditnz.govt.nz: http://www.auditnz.govt.nz/publications-resources/assurance/asset-management/asset-management-for-public-entities/publications-resources/assetmanagement.pdf

Office of the Auditor General, New Zealand. (2004, January 1). *Part 5: Life cycle costing analysis-Office of the Auditor-General New Zealand*. Retrieved September 19, 2014, from www.oag.govt.nz: http://www.oag.govt.nz/2004/lav/part5.htm

Office of the Auditor-General New Zealand. (2014, September 23). *Part 5: Life cycle costing analysis - Office of the Auditor-General New Zealand:*. Retrieved September 19, 2014, from www.oag.govt.nz: http://www.oag.govt/nz/2004/lav/part5.htm

Office of the Auditor-General New Zealand. (2014, September 23). *www.oag.govt.nz/2004/lav/part5.htm*. Retrieved September 19, 2014, from www.oag.govt.nz: http://www.oag.govt.nz/2004/lav/part5.htm

Oil and Gas UK. (2010, January 1). *HS022 - Asset Integrity Toolkit (2006)*. (Oxford Web Applications) Retrieved December 1, 2014, from http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=225: http://www.oilandgasuk.co.uk/AssetIntegrity.cfm

Oil and Gas UK. (2013, January 23). *Supply Chain Code of Practice*. Retrieved December 1, 2014, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68823/2819-pilot-supply-chain-code-of-practice-sccop.pdf: https://www.gov.uk/government/groups/105

Oil and Gas UK LOGIC. (2014, January 1). *Governance for Standard Industry Solutions IMHH.* Retrieved December 2, 2014, from http://www.logic-oil.com/imhh: http://www.logic-oil.com/master-deed

Oil Spill Prevention and Response Advisory Group. (2011). *Strengthening UK Prevention and Response.* UK Oil Spill Prevention and Response Advisory Group. Retrieved from http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/EN022.pdf

Petroleum Safety Authority. (2010). *Trends in Risk Level in Petroleum Activity.* Retrieved February 16, 2015, from http://www.ptil.no/getfile.php/PDF/RNNP%202010/Summary_Report_2010_rev1a1.pdf

Petroleum Safety Authority. (2012, July 23). *Safety Performance Indicators.* Retrieved April 27, 2015, from http://www.csb.gov/UserFiles/file/Lauridsen%20(PSA)%20Paper%20-%20printed(1).pdf

Petroleum Safety Authority. (2013). *Damage and incidents involving load-bearing structures and pipeline systems.* Retrieved April 27, 2015, from http://www.psa.no/facts-and-statistics/category921.html

Petroleum Safety Authority. (2013, March 1). *Petroleum Safety Authority Norway's (PSA's) report from the DSYS diving database.* Retrieved April 27, 2015, from http://www.ptil.no/news/report-incidents-in-connection-with-diving-article9222-878.html

Petroleum Safety Authority. (2014, September 24). *About Us*. Retrieved September 24, 2014, from Petroleum Safety Authority: http://www.psa.no/about-us/category877.html

Petroleum Safety Authority. (2014). *Framework HSE*. Retrieved September 30, 2014, from http://www.psa.no/framework-hse/category403.html

Petroleum Safety Authority. (2014, December 16). *Guidelines Regarding the Management Regulations.* Retrieved February 16, 2015, from http://www.psa.no/management/category406.html#_Toc377973133

Petroleum Safety Authority. (2014, December 16). *Guidelines Regarding the Management Regulations.* Retrieved February 16, 2015, from http://www.psa.no/management/category401.html

Petroleum Safety Authority. (2014, September 24). *Management*. Retrieved September 24, 2014, from Petroleum Safety Authority: http://www.psa.no/management/category406.html#p20

Petroleum Safety Authority. (2014, September 24). *Regulations*. Retrieved September 24, 2014, from Petroleum Safety Authority: http://www.psa.no/regulations/category216.html

Petroleum Safety Authority. (2014, December 16). *Regulations Relating to Management and the Duty to Provide Information in the Petroleum Activities and at Certain Oshore Facilities.* Retrieved February 16, 2015, from http://www.psa.no/management/category401.html

Petroleum Safety Authority. (2015). *All operators conducting drilling on the Norwegian continental shelf are required to report data from this activity to the authorities on a daily basis.* Retrieved April 27, 2015, from http://www.psa.no/drilling-reports-ddrs/category939.html

Petroleum Safety Authority. (2015). *HSE Regulations.* Retrieved April 29, 2015, from http://www.psa.no/about-the-hse-regulation/category929.html

Petroleum Safety Authority. (2015, April 8). *Production Licenses.* Retrieved April 29, 2015, from http://www.npd.no/en/Topics/Production-licences/Theme-articles/Pre-qualification/

Petroleum Safety Authority. (n.d.). *Confirming the notification/report of hazards and accidents (offshore and on land).* Retrieved February 18, 2015, from http://www.psa.no/report-about-situation-of-hazard-and-accident/category935.html

Petroleum Safety Authority Norway. (2013). *Annual Report 2013.* PSA Norway. Retrieved from http://www.ptil.no/publikasjoner/Annualreport2013/HTML/index.html#/2/

Petroleum Safety Authority Norway. (2013). *Trends in Risk Level in the Petroleum Activity - Summary Report 2013.* Retrieved from http://www.psa.no/getfile.php/PDF/RNNP_2013/Trends%20summary%202013.pdf

PHMSA. (2015, February 26). *Pipeline and Hazardous Materials Safety Administration*. Retrieved from Integrity Management Program (IMP): http://primis.phmsa.dot.gov/gasimp/

Pipeline and Hazardous Materials Safety Administration. (n.d.). *Pipeline Inspections 101*. Retrieved from http://phmsa.dot.gov/pipeline/inspections

Prevention, C. f. (2014, April 14). *Mission, Role and Pledge*. Retrieved from Centers for Disease Control and Prevention: http://www.cdc.gov/about/organization/mission.htm

PTC. (2015, January 1). *PTC Corrective Action System*. Retrieved April 10, 2015, from http://www.ptc.com/product-lifecycle-management/windchill/fracas: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&sqi=2&ved=0CDEQFjAA&url=http%3A%2F%2Fwww.ptc.com%2Fproduct-lifecycle-management%2Fwindchill%2Ffracas&ei=OP4nVa_8OYqoogTGkIHQDQ&usg=AFQjCNG321VvuzMl6FqDLzRNfBl4Vs8pEA&sig2=QoiGX9zcZe2e_VvjPbUR0

Raya Fidel, H. S. (2007). Mobile Government Fieldwork: A Preliminary Study of Technological, Organizational, and Social Challenges. *The Proceedings of the 8th Annual International Digital Government Research Conference* (pp. 131-137). Seattle: The Information School, University of Washington. Retrieved December 19, 2014

Raytheon. (2013, July 13). *FRACAS*. Retrieved April 13, 2015, from https://www.raytheoneagle.com/asent/fracas.htm: https://www.raytheoneagle.com/asent/fracas.htm

Raytheon. (2014, July 7). *Advanced Specialty Engineering Networked Toolkit (ASENT)*. Retrieved April 13, 2015, from https://www.raytheoneagle.com/asent/index.htm: https://www.raytheoneagle.com/asent/index.htm

Reidel, J. (2014, October 8). *New Study Examines Role of Government in Deepwater Horizon Oil Spill.* Retrieved December 7, 2014, from Doctoral Programs in Educational Leadership and Policy Studies: http://www.uvm.edu/~cess/doctoral/?Page=news&storyID=19337&category=ucommall

Reliability Analysis Center (RAC). (2008, November 26). FRACAS Section 1: The Generic FRACAS (Abbreviated Section) . *FRACAS Section 1: The Generic FRACAS (Abbreviated Section)* . Rome,, New York, United States. Retrieved February 10, 2015, from https://src.alionscience.com/pdf/RAC-1ST/FRACAS_1ST.pdf: https://src.alionscience.com/pdf/RAC-1ST/FRACAS_1ST.pdf

(2006). *Reliability Centered Maintenance (RCM) Process Guide, CGTO PG-85-00-30 .* Washington D.C. : U.S. Coast Guard .

ReliaSoft. (2011). *Reliability Hotwire*. Retrieved December 15, 2014, from http://www.weibull.com/hotwire/issue122/relbasics122.htm

ReliaSoft. (2014). *Reliability, Software, Training and Services*. Retrieved September 30, 2014, from http://www.reliasoft.com/corporate/index.htm

ReliaSoft. (2015, January 25). *XFRACAS System Features*. Retrieved December 15, 2014, from http://www.reliasoft.com/xfracas/features1.htm

ReliaSoft. (n.d.). *XFRACAS System Features*. Retrieved December 15, 2014, from http://www.reliasoft.com/xfracas/features1.htm

Rigzone. (2008, April 17). *PSA Norway Issues Report On Life Extension For Aging Facilities*. Retrieved January 6, 2015, from http://www.rigzone.com/news/article.asp?a_id=60477&rss=true

Roger R. Hill, J. A., & Dr. Allan S. Benjamin and James Linsday, A. C. (2008). *Wind Turbine Reliability: A Database and Analysis Approach.* Albquerque: Sandia National Laboratories. Retrieved January 23, 2015, from http://prod.sandia.gov/techlib/access-control.cgi/2008/080983.pdf

Science Applications International Corporation. (1986). *Improved Reliability for Analog Instrument and Control Systems, Volume 1: Failure Analysis and Demonstration Module; and Volume 2: Guidelines for Component Selection and Replacement.* Palo Alto: Electric Power Research Institute. Retrieved from http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=NP-4483-V1

SEMATEC. (n.d.). *Home*. Retrieved September 30, 2014, from http://public.sematech.org/Pages/home.aspx

SME, S. O. (2014, December 8). Interview with senior Oil And Natural Gas Subject Matter Expert. (J. C. Hendrickson, Interviewer)

Smith, E. (2013, October 31). *BSEE Regulatory Developments.* Retrieved December 7, 2014, from https://www.haynesboone.com/files/Uploads/Documents/OFSR-BSEE-10-31-2013.pdf

State of California. (2010, January 1). *Project Life Cycle Framework*. Retrieved September 29, 2014, from www.bestpractices.osi.ca.gov: http://www.bestpractices.osi.ca.gov/sysacq/projectlifecycle.shtml

State of California. (2014, January 1). California Laws for Conservation of Petroleum and Gas. *PUBLICATION NO. PRC01*. Sacramento, California, United States. Retrieved September 29, 2014, from ftp://ftp.consrv.ca.gov/pub/oil/laws/PRC01.pdf

Susan Olenchuk, J. C. (2012). The Potential Impact of New Pipeline Safety Laws on PHMSA's Regulatory Initiatives. *Pipeline and Gas Journal, 239*(4). Retrieved January 27, 2015, from http://www.vnf.com/693

Swinney, J. S. (2010). Enterprise Resource Management System Implementation - A Sewer District Case Study. *Proceedings Of the Water Environment Federation* (pp. 5233-5236). Alexandria, VA: Water Environment Federation. Retrieved December 19, 2014

The Marine Board of the National Research Council. (1984). *Safety Information and Management on the Outer Continental Shelf.* Washington, D.C.: National Academy Press.

The National Archives. (2014). *The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996*. Retrieved September 23, 2014, from legislation.gov.uk: http://www.legislation.gov.uk/uksi/1996/913/contents/made

The Times-Picayune. (2013, March 26). *Oil platform owner sued over Nov. 16 explosion*. Retrieved December 7, 2014, from www.nola.com: http://www.nola.com/business/index.ssf/2013/03/oil_platform_owner_sued_over_n.html

The U.K. Oil and Gas Industry Association. (2010, January 1). *Oil and Gas UK, About Us*. (Oxford Web Applications) Retrieved December 1, 2014, from http://www.oilandgasuk.co.uk/aboutus/aboutus.cfm: http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=252

The U.K. Oil and Gas Industry Association. (2010, January 1). *Oil and Gas UK, About Us, Subsidiaries*. (Oxford Web Applications) Retrieved December 1, 2014, from http://www.oilandgasuk.co.uk/aboutus/subsidiaries.cfm: http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=252

The U.K. Oil and Gas Industry Association. (2010, January 1). *Oil and Gas UK, About Us, Subsidiaries*. (Oxford Web Applications) Retrieved December 1, 2014, from http://www.oilandgasuk.co.uk/aboutus/subsidiaries.cfm: http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=252

The UK Oil and Gas Industry Association. (2010, January 1). *Oil and Gas UK, About Us*. (Oxford Web Applications) Retrieved December 1, 2014, from http://www.oilandgasuk.co.uk/aboutus/aboutus.cfm: http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=252

Thibalt, R. (2013, October 31). *www.haynesboone.com.* Retrieved December 7, 2014, from https://www.haynesboone.com/files/Uploads/Documents/OFSR-BSEE-10-31-2013.pdf

Thomas, I. (. (2005). *Environmental management: processes and practices in Australia/Ian Thomas.* Annandale, N.S.W.: Federation Press. Retrieved September 30, 2014

Toevs, G. R., MacKinnon, W. C., & Bobo, M. R. (2011, August). *Assessment, Inventory, and Monitoring Strategy: For integrated renewable resources management.* Washington, D.C.: U.S. Department of Interior Bureau of Land Management. Retrieved September 29, 2014, from http://www.blm.gov/pgdata/etc/medialib/blm/wo/Information_Resources_Management/policy/ib_attachments/2012.Par.53766.File.dat/IB2012-080_att1.pdf

Transportation Research Board. (2003). *Safety Management Systems: A Synthesis of Highway Practice*. Retrieved from https://books.google.com/books?id=ryLyQk_b7A0C&source=gbs_navlinks_s

Transportation Research Board. (2003). *Safety Management Systems: A Synthesis of Highway Practice*. Retrieved January 1, 2015, from https://books.google.com/books?id=ryLyQk_b7A0C&source=gbs_navlinks_s

Transportation Research Board of the National Academies. (2009). *Hazardous Materials Transportation Incident Data for Root Cause Analysis.* Colombus, OH: BATTELLE MEMORIAL INSTITUTE.

TREASURY, N. S. (2012, August 20). *www.treasury.nsw.gov.au.* Retrieved September 18, 2014, from www.treasury.nsw.gov.au: http://www.treasury.nsw.gov.au/ data/assets/pdf file/0005/5099/life cycle costings.pdf

U.K. Government. (2014, December 2). *PILOT.* Retrieved December 2, 2014, from https://www.gov.uk/government/groups/105: https://www.gov.uk/government/groups/105

U.K. Government. (2014, December 2). *PILOT.* Retrieved December 2, 2014, from https://www.gov.uk/government/groups/105: https://www.gov.uk/government/groups/105

U.K. Health and Safety Executive. (2003). *RR076 - Machinery and rotating equipment integrity inspection guidance notes*. Retrieved January 2, 2015, from http://www.hse.gov.uk/research/rrhtm/rr076.htm

U.K. Health and Safety Executive. (2004). *RR253 - Piping Systems Integrity: Management review*. Retrieved January 2, 2015, from http://www.hse.gov.uk/research/rrhtm/rr253.htm

U.K. Health and Safety Executive. (2006). *RR509 - Plant ageing: Management of equipment containing hazardous fluids or pressure*. Retrieved January 2, 2015, from http://www.hse.gov.uk/research/rrhtm/rr509.htm

U.K. Health and Safety Executive. (2012, September). *KP4 Technical Policies*. Retrieved January 2, 2015, from http://www.hse.gov.uk/offshore/ageing/kp4-technical-policy.pdf

U.K. Health and Safety Executive. (2014, October). *Background Quality Report: Injury statistics as reported under RIDDOR*. Retrieved January 8, 2015, from http://www.hse.gov.uk/statistics/pdf/riddor-background-quality-report.pdf

U.K. Health and Safety Executive. (2014, October). *Health and Safety Statistics 2013/2014: Annual Report for Great Britain*. Retrieved January 8, 2015, from http://www.hse.gov.uk/statistics/overall/hssh1314.pdf

U.K. Health and Safety Executive. (2014, May). *Key Programme 4 (KP4) Ageing and life extension programme*. Retrieved December 31, 2014, from http://www.hse.gov.uk/offshore/ageing/kp4-report.pdf

U.K. Health and Safety Executive. (2014, May). *Key Programme 4 (KP4) Ageing and life extension programme*. Retrieved December 31, 2014, from http://www.hse.gov.uk/offshore/ageing/kp4-report.pdf

U.K. Health and Safety Executive. (2014). *Managing Ageing Plant: A Summary Guide*. Retrieved January 2, 2015, from http://www.hse.gov.uk/offshore/ageing/ageing-plant-summary-guide.pdf

U.K. Health and Safety Executive. (2014, January 1). *Managing Ageing Plant: A Summary Guide*. Retrieved January 2, 2015, from http://www.hse.gov.uk/offshore/ageing/ageing-plant-summary-guide.pdf

U.K. Health and Safety Executive. (2014, January 1). *Managing Ageing Plant: A Summary Guide*. Retrieved January 2, 2015, from http://www.hse.gov.uk/offshore/ageing/ageing-plant-summary-guide.pdf

U.K. Health and Safety Executive. (n.d.). *How to Make a RIDDOR report*. Retrieved January 8, 2015, from http://www.hse.gov.uk/riddor/report.htm

U.S Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 28). *Gas Transmission Integrity Management: Fact Sheet*. Retrieved January 28, 2015, from http://primis.phmsa.dot.gov/: http://primis.phmsa.dot.gov/gasimp/fact.htm

U.S. Coast Guard. (2006). *46 U.S.C. 3717* . Retrieved May 19, 2015, from Marine safety information system: http://www.gpo.gov/fdsys/granule/USCODE-2011-title46/USCODE-2011-title46-subtitleII-partB-chap37-sec3717

U.S. Coast Guard. (2013, March 17). *United States Coast Guard Risk Management Overview.* Retrieved May 19, 2015, from http://www.orau.gov/DHSsummit/presentations/March17/plenary/Cooper_Mar17.pdf

U.S. Department of Defense. (2014, September 29). *About the Department of Defense*. (U. D. Defense, Producer) Retrieved September 29, 2014, from U.S. Department of Defense: http://www.defense.gov/about/#mission

U.S. Department of Energy. (2009, March 9). DOE Solar Energy Technologies Program Peer Review. *DOE Solar Energy Technologies Program Peer Review*. Denver, Colorado, U.S.A. Retrieved April 14, 2015, from http://www1.eere.energy.gov/solar/review_meeting/pdfs/prm2009_granata_reliability.pdf

U.S. Department of Energy. (2014, September 29). *Mission*. Retrieved September 29, 2014, from U.S. Department of Energy: http://www.energy.gov/mission

U.S. Department of Transportation - Hazardous Materials and Safety Administration. (2015, January 28). DIMP Introduction. Washington, District of Colombia, United States. Retrieved January 28, 2015, from http://www.phmsa.dot.gov/staticfiles/PHMSA/flash/chapter1.html

U.S. Department of Transportation - Hazardous Materials and Safety Administration. (2015, January 28). *Hazardous Liquid Integrity Management: Fact Sheet*. Retrieved January 28, 2015, from http://primis.phmsa.dot.gov: http://primis.phmsa.dot.gov/iim/fact.htm

U.S. Department of Transportation - Hazardous Materials and Safety Administration. (2015, January 27). *Instructions for Completing the Hazardous Materials Incident Report – Department of Transportation Form F 5800.1*. Retrieved January 27, 2015, from https://hazmatonline.phmsa.dot.gov/: https://hazmatonline.phmsa.dot.gov/incident/Details0.htm

U.S. Department of Transportation - Pipeline and Hazardous Materials and Safety Administration. (2015, January 28). *Hazardous Liquid Integrity Management: Fact Sheet*. Retrieved January 28, 2015, from http://primis.phmsa.dot.gov: http://primis.phmsa.dot.gov/iim/fact.htm

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2014). *Form PHMSA F7100.3 rev 10-2014.* Retrieved from http://phmsa.dot.gov: http://phmsa.dot.gov/pv_obj_cache/pv_obj_id_94AAD4CA43883C7ED3A95EC14BAF210D197D0100/filename/LNG_Incident_Form_PHMSA_F_7100.3_(rev10_2014).pdf

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2014, July 23). *U.S. DOT Announces Comprehensive Proposed Rulemaking for the Safe Transportation of Crude Oil, Flammable Materials*. Retrieved January 29, 2015, from http://www.dot.gov/briefing-room/: http://www.dot.gov/briefing-room/us-dot-announces-comprehensive-proposed-rulemaking-safe-transportation-crude-oil

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 20). *About the Agency*. Retrieved January 20, 2015, from About PHMSA: http://www.phmsa.dot.gov/about/agency

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 20). *FAQs*. Retrieved January 20, 2015, from PHMSA and Pipelines FAQs - What is Integrity Management of Pipelines: http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=ea758c3936f40110VgnVCM100000762c7798RCRD&vgnextchannel=f7280665b91ac010VgnVCM1000008049a8c0RCRD

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 28). *Gas Distribution Integrity Management Program*. Retrieved January 28, 2015, from http://primis.phmsa.dot.gov/: http://primis.phmsa.dot.gov/dimp/index.htm

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 28). *Gas Transmission Integrity Management: Fact Sheet*. Retrieved January 28, 2015, from http://primis.phmsa.dot.gov/: http://primis.phmsa.dot.gov/gasimp/fact.htm

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 27). *Incident Reporting*. Retrieved January 27, 2015, from http://www.phmsa.dot.gov/: http://www.phmsa.dot.gov/incident-report

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015, January 20). *Mechanical Fitting Failure Data from Gas Distribution Operators*. Retrieved January 20, 2015, from phmsa.dot.gov: http://phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=06cc95f181584410VgnVCM100000d2c97898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print

U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration. (2015). *Operation Safe Delivery Update.* U.S. Department of Transportation - Pipeline and Hazardous Materials Safety Administration.

U.S. Department of Transportation - Pipeline Safety and Hazardous Materials Safety Administration. (2015, January 30). *Mission and Goals*. Retrieved January 30, 2015, from http://www.phmsa.dot.gov: http://www.phmsa.dot.gov/about/mission

U.S. Department of Transportation. (2004). *Guide for Preparing Hazardous Materials Incidents Reports.* Pipeline and Hazardous Materials Safety Administration. Retrieved from http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_E48DC74FFC5E921568E9E899FA06C94EA17B4200/filename/reporting_instructions_rev.pdf

U.S. Department of Transportation. (2015). *PHMSA Portal*. Retrieved 2015, from https://portal.phmsa.dot.gov/portal

U.S. Department of Transportation Maritime Administration. (2014, September 29). *About Us*. (Maratime Administration) Retrieved September 29, 2014, from Maritime Administration: http://www.marad.dot.gov/about_us_landing_page/about_us_landing_page.htm

U.S. Department of Transportation Pipeline and Hazardous Materials Safety. (2011). *Distribution Integrity Management Program (DIMP) History.* Washington, DC: U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. Retrieved Feburary 5, 2015, from https://primis.phmsa.dot.gov/dimp/docs/History_of_DIMP_06152011.pdf

U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. (2004). Retrieved from http://www.phmsa.dot.gov: http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_70F9D658169CB0F2B75FFC057AB28F96F1780300/filename/IncidentForm010105.pdf

U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. (2014, April 7). *PHMSA's Proposed Pipeline Penalties Hit All-Time High; Serious Pipeline Incident Count Hits All-Time Low.* Retrieved January 5, 2015, from http://www.phmsa.dot.gov/: http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=9c7c87c1a3e25410VgnVCM100000d2c97898RCRD&vgnextchannel=d248724dd7d6c010VgnVCM10000080e8a8c0RCRD&vgnextfmt=print

U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. (n.d.). *Hazardous Liquid Integrity Management Flowchart.* Retrieved from https://primis.phmsa.dot.gov/iim/flowchart.htm

U.S. Department of Transportations Pipeline and Hazardous Materials Safety Administration. (2015, February 5). *Data and Statistics*. Retrieved February 5, 2015, from http://phmsa.dot.gov/: http://phmsa.dot.gov/resources/data-stats

U.S. Department of Trasportation Maritime Administration. (2006). Comprehensive Management Plan for the Disposal of Maritime Administration Non-Retention Vessels. Retrieved from http://www.marad.dot.gov/documents/ShipDispComprehensiveMgmntPlan.pdf

U.S. Food and Drug Administration. (2014, September 17). *MedWatch: The FDA Information and Adverse Event Reporting Program*. Retrieved from U.S. Food and Drug Administration: http://www.fda.gov/Safety/MedWatch/default.htm

U.S. Food and Drug Administration. (2014, August 5). *What we do.* Retrieved from U.S. Food and Drug Administration: http://www.fda.gov/AboutFDA/WhatWeDo/default.htm

U.S. Food and Drug Administration. (2014, August 5). *What we do*. (U. F. Administration, Producer) Retrieved September 29, 2014, from U.S. Food and Drug Administration: http://www.fda.gov/AboutFDA/WhatWeDo/default.htm

U.S. Nuclear Regulatory Commission. (2014, December 12). *Backgrounder on Nuclear Insurance and Disaster Relief*. Retrieved 4 21, 2015, from http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/nuclear-insurance.html

UK Health and Safety Executive. (2003). *RR076 - Machinery and rotating equipment integrity inspection guidance notes*. Retrieved January 2, 2015, from http://www.hse.gov.uk/research/rrhtm/rr076.htm

UK Health and Safety Executive. (2004). *RR253 - Piping Systems Integrity: Management review*. Retrieved January 2, 2015, from http://www.hse.gov.uk/research/rrhtm/rr253.htm

UK Health and Safety Executive. (2006). *RR509 - Plant ageing: Management of equipment containing hazardous fluids or pressure*. Retrieved January 2, 2015, from http://www.hse.gov.uk/research/rrhtm/rr509.htm

UK Health and Safety Executive. (2012, September). *KP4 Technical Policies*. Retrieved January 2, 2015, from http://www.hse.gov.uk/offshore/ageing/kp4-technical-policy.pdf

UK Health and Safety Executive. (2014, October). *Background Quality Report: Injury statistics as reported under RIDDOR*. Retrieved January 8, 2015, from http://www.hse.gov.uk/statistics/pdf/riddor-background-quality-report.pdf

UK Health and Safety Executive. (2014, October). *Health and Safety Statistics 2013/2014: Annual Report for Great Britain*. Retrieved January 8, 2015, from http://www.hse.gov.uk/statistics/overall/hssh1314.pdf

UK Health and Safety Executive. (2014). *How to Make a RIDDOR report*. Retrieved January 8, 2015, from http://www.hse.gov.uk/riddor/report.htm

UK Health and Safety Executive. (2014, May). *Key Programme 4 (KP4) Ageing and life extension programme*. Retrieved December 31, 2014, from http://www.hse.gov.uk/offshore/ageing/kp4-report.pdf

UK Health and Safety Executive. (2014). *Managing Ageing Plant: A Summary Guide*. Retrieved January 2, 2015, from http://www.hse.gov.uk/offshore/ageing/ageing-plant-summary-guide.pdf

UK Health and Safety Executive. (2014). *Types of reportable incidents*. Retrieved January 5, 2015, from http://www.hse.gov.uk/riddor/reportable-incidents.htm

UK Health and Safety Executive. (2014, January 1). *Types of reportable incidents*. Retrieved January 5, 2015, from http://www.hse.gov.uk/riddor/reportable-incidents.htm

UK Health and Safety Executive. (n.d.). *How to Make a RIDDOR report*. Retrieved January 8, 2015, from http://www.hse.gov.uk/riddor/report.htm

UK Health and Safety Executive. (n.d.). *Key definitions*. Retrieved 2015, from Health and Safety Executive: http://www.hse.gov.uk/riddor/key-definitions.htm

UK Health and Safety Executive. (n.d.). *What records do I need to keep?* Retrieved May 2015, from Health and Safety Executive: http://www.hse.gov.uk/riddor/what-must-i-keep.htm

United States Coast Guard. (2012, March 23). *Letter to the IADC*. Retrieved December 17, 2014, from http://www.iadc.org/wp-content/uploads/20120323-USCG-D8dp-response-to-MSIB-Ltr.pdf

United States Coast Guard. (2013, August 15). Casualty Reporting (CASREP) Tactics, Techniques, and Procedures (TTP). Washington, Distric of Columbia, United States: United State Coast Guard. Retrieved September 30, 2014, from http://www.uscg.mil/forcecom/ttp/pubs/CGTTP_6-01_3_CASREP.pdf

United States Coast Guard. (2014, November 25). *Reporting Marine Casualties*. Retrieved Feburary 17, 2015, from http://www.uscg.mil/: http://www.uscg.mil/acteur/reporting.asp

United States Coast Guard. (2015, February 17). Report Marine Casualties. Riviera, Florida, United States of America. Retrieved Febuary 17, 2015, from http://www.uscg.mil/d7/sectMiami/pdf/RMCBrochureMSDLW.pdf

United States Coast Guard. (n.d.). Coast Guard Reporting in the Artic and in Western Alaska (west of 148*26). Retrieved Feburary 17, 2015, from http://www.uscg.mil/d17/sectoranchorage/docs/reporting.pdf

United States Department of Defence. (1995, December 11). DEPARTMENT OF DEFENSE HANDBOOK, FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION TAKEN. *FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION TAKEN, Mil-SId-2 155(AS)*. Washington, District of Columbia, United States: Department of Defence. Retrieved February 9, 2015, from http://everyspec.com/MIL-HDBK/MIL-HDBK-2000-2999/MIL-HDBK-2155_21714/

United States Department of Health and Human Services. (2012, July 18). *Enterprise Performance Life Cycle Performance Framework.* Retrieved from Centers for Disease Control and Prevention: http://www2a.cdc.gov/cdcup/library/hhs_eplc/EPLC_Framework_09-18-12.pdf

United States Environemental Protection Agency. (2014, July 31). *Report Environmental Violations*. (U. S. Agency, Producer) Retrieved September 29, 2014, from United States Environmental Protection Agency: http://www2.epa.gov/enforcement/report-environmental-violations

United States Environmental Protection Agency. (2014, September 30). *US Environmental Protection Agency*. (U. E. Agency, Producer) Retrieved September 30, 2014, from United States Environmental Protection Agency: http://epa.gov/

United States Nuclear Regulatory Committee. (2014, September 8). *Licensee Event Report Search*. (United States Nuclear Regulatory Committee) Retrieved September 30, 2014, from United States Nuclear Regulatory Committee: https://lersearch.inl.gov/Entry.aspx

USDA.gov. (2014, April 15). *Mission Statement | USDA.* Retrieved September 23, 2014, from United States Department of Agriculture : http://www.usda/gov/wps/portal/usda/usdahome?navid=MISSION_STATEMENT

Venkatramam, V. (2015, January 22). Genesis Solitions Marketing and Sales Senior Director. (J. Hendrickson, Interviewer)

Venkatramam, V. (2015, January 22). Genesis Solutions Marketing and Sales Senior Director. (J. Hendrickson, Interviewer)

Vivastream. (2014, September 26). *Transportation MUG: How Amtrak Is Utilizing Maximo Mobile across the Asset Lifecyle to Ensure Accuracy, Safety and Compliance.* Retrieved September 26, 2014, from https://www.vivastream.com/events/pulse2013/sessions/2048

Weibull. (2011, April). *Reliability Basics*. Retrieved January 12, 2015, from Weibull.com: http://www.weibull.com/hotwire/issue122/relbasics122.htm

Willis, R. (2006, April 1). *Survey of Support Software for Reliability Engineering*. Retrieved December 18, 2014, from http://procon.bg/bg/article/survey-support-software-reliability-engineering

Wintle, J., & Sharp, J. (2008, January). *Requirements for Life Extension of Ageing Offshore Production Installations*. Retrieved January 6, 2015, from http://www.ptil.no/getfile.php/PDF/Requirements%20for%20Life%20Extension%20of%20Ageing%20Offshore%20Production%20Installations.pdf

Wintle, J., Kenzie, B., Amphlett, G., & Smalley, S. (2008). *Best practice for risk based inspection as a part of plant integrity management*. Retrieved January 6, 2015, from http://www.hse.gov.uk/research/crr_pdf/2001/crr01363.pdf

Wintle, J., Kenzie, B., Amphlett, G., & Smalley, S. (2008, January 6). *Best practice for risk based inspection as a part of plant integrity management*. Retrieved January 6, 2015, from http://www.hse.gov.uk/research/crr_pdf/2001/crr01363.pdf